VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CXXXIX.—SEPTEMBER, 1880.—VOL. XXIII.

THE STRUCTURE OF STEEL INGOTS.

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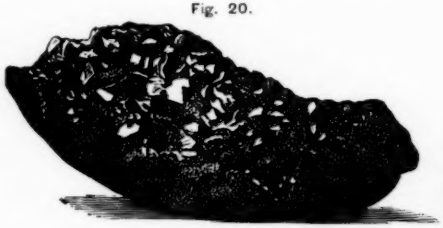
Translated from Revue Universelle des Mines.

II.

THE feeble cohesion between the prisms is the principal cause of the cracks which appear on the surface of the ingot as it cools. Any inequality in the surface of the ingot, which prevents the contraction of the cooling crust, causes the cohesion of the prisms to be overcome, so that the surface layer instead of extending, cracks open, and this tendency is greater the higher the temperature of the metal.

Fig. 20.



The sides of a crack are of prismatic texture, and the lateral surfaces of the prisms show the impression of the axes of the neighboring prisms. Figure 18, exhibits in natural size one side of a crevice produced at bright red heat, by the hardening of the crust while yet liquid on the exterior.

In the case of an ingot of large diameter (0m.750 to 1m.30) and of considerable height (2 to 3 meters), if the steel is very hot and poured rapidly, the expansion of the sides of the mould, being opposed to the contraction of the adherent layers of steel, exerts a great influence upon the formation of cracks in the outer surface of the ingot.

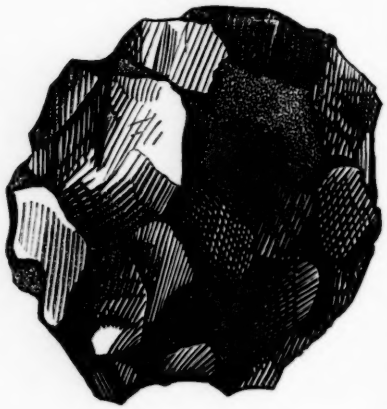
Fig. 21.

The prismatic structure of the exterior of an ingot beyond these cracks leads to the want of cohesion. During

the continuous cooling, and while the volume of the outer layers is diminishing, these latter cannot compress the inner portions which cool more slowly, and this leads to the rupture of the prisms, so that in the exterior portions the effect of cooling is exhibited less by the elongation of the metal, than by the separation of the prisms each from the other, and in such cases involves nearly all the prisms in the ruptured surface (see Fig. 18).

Whatever the origin of the granulation which follows the outside prismatic layer, it is well explained by the elongation of metal when the ingot cools. We have already remarked above that in the slow cooling of steel which has been cast very hot, there results a peculiar

Fig. 22.



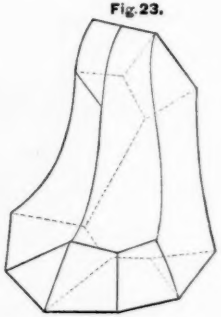
grouping of the molecules in irregular polygonal grains. If, during such grouping, there should be produced, while yet red hot, a rupture of the cohesion, by the action of the exterior forces either of extension or contraction, it is easy to see that the grains would be torn asunder, and that the fracture would exhibit separate grains. As while the temperature lowers from the beginning of the hardening down to the ordinary temperature, the direction of the extensions in different parts of the ingot changes repeatedly, it follows that similar granulations may occur in all parts of the ingot, but more abundantly in the exterior and central layers, and more especially in ingots of large diameter, where the difference in the temperature between the inner and outer portions is greater. It is well to note that in large ingots the outside portions are at first subjected to a force of extension, while the inner portions are compressed. At the end of the cooling, on the contrary, the outer layers are compressed and the inner extended.

The elongation of the interior portions of large ingots (of one meter in diameter) is so great that, when the ingot is exposed to the air to cool it presents, when cooled, interior cracks, generally in the portion where it is the weakest.

A single granule of steel, enlarged about three times, is shown in figure 22. Another one, from a different source, is exhibited in figure 23.

Figures 20 and 21 represent on a re-

Fig. 23.



duced scale (about one-third size), fractures of a highly granulated steel.

These sketches show that the grains bear only a feeble resemblance to crystals; no regularity of form is apparent; for, besides the complete diversity of angles, there is a distortion not less complete of the faces.

We will now consider the means of dealing with the defects we have been describing.

As an indirect method I will refer to the preparation of malleable cast-iron. In casting pieces of clear white cast iron, and heating them for a long time in an oxidizing medium, a product is obtained which is more or less decarbonized and is not especially different from either steel or wrought iron.

This method does not really solve the problem, for the metal obtained by this process is far from possessing the properties which we look for, although malleable cast iron has found many useful applications, especially in locksmithing.

Without considering longer this indirect method, we will proceed at once to consider the means of combating the defects of ingot steel.

There are three methods:

1. Casting the ingot in the simplest form, and then shaping it by hammering and rolling.

2. Subjecting the steel while in the liquid state to a strong pressure, and obtaining an ingot without bubbles, and (in part) without a shrinkage cavity, then rolling or hammering as before.

3. Arresting by some chemical process the disengagement of gas from the melted steel, and then casting the steel in metal or sand moulds in the desired forms.

In the first case, the structure of the ingot would be similar to that of figure 1. The defects developed are of the two kinds shown in the right and left hand sides of the figure. The upper part of the ingot full of cavities is rejected. It forms from one-fourth to one-sixth of the weight of the ingot. The remaining part only is used for purposes of manufacture. The use of steel at the present time for armor and heavy artillery requires ingots of large dimensions. A corresponding increase in the size of machines to work these ingots is, of course, demanded. The hammer of fifty tons has become insufficient. At the Paris Exposition of 1878, a mould of a stamp of eighty tons was exhibited, designed to work an ingot of 120 tons, of which the model in wood was also shown. During a visit to the steel works at St. Chamond, I saw a double-acting steam hammer of eighty tons in actual operation, and it is proposed to construct at Krupp's works a steam hammer of 100 tons weight. I regret that I do not know the present condition of this question.

In order to avoid unnecessary labor in forging, they try to cast the ingots of such a thickness that the transverse section is double that of the piece desired. In preserving this ratio of thicknesses the exterior porous layer, diminished by oxidation during the working, as well as a certain thickness removed by turning or planing, leaves sufficient to admit polishing the finished piece. This metal removed by turning or planing is in many cases from 10 to 20 per cent. of the weight of the finished piece; so that this added to the rejected upper part of the ingot represents a considerable loss.

It is well to remark that in working thus, the porousness of the interior portions of the ingot, that is to say, the area of local contraction diminishes slightly in the direction of the length, by reason of the lengthening of the shrinkage cavities in common with the metal surrounding them.

In the cross section of the ingot the influence of the local contraction upon the solidity of the steel is yet more sensible. This becomes apparent by experimenting upon the strength of different layers of a large rolled ingot. The following table exhibits results of some experiments.

Figure 26 represents an ingot of diameter D′ hammered to the diameter D. A hole of diameter d is drilled through the ingot. Then thin laminae a have been cut parallel to the axis of the ingot and subjected to a tensile force in a testing machine. The diameters D′, D, and d are variable.

D′	D	d	Number of the Slice.	Limit of Elasticity in Atmospheres.	Breaking Strain in Atmospheres.	Elongation. Per cent.
in inches.						
47,5	36,5	11	1	1800	5300	16,0
			7	2330	6200	17,0
42,5	32,5	9	2	1980	5200	18,0
			6	2500	6400	16,0
36,5	26,5	8	2	1800	5830	13,7
			5	2380	6540	14,8
36,5	26,5	8	1	1860	4517	16,0
			7	2910	6585	15,0

As the ingots from which these specimens have been obtained were forged, it is fair to inquire whether the difference in strength of the interior and exterior layers may not be explained as due to the working. It is necessary to remark that these ingots, after having been rolled were heated and then more or less slowly cooled; and as in this operation the different layers of the ingot

were not under identical conditions, each separate sample before testing was reheated and cooled slowly; so that the influence of the working upon the ingot was much reduced, and the difference in strength is fairly to be attributed to the influence of the local contraction cavities. It is to be regretted that no similar experiments were made upon ingots of similar dimensions that had not been forged.

In order to be convinced of the existence of these cavities of local contraction, it is only necessary to examine Figures 24 and 25 which represent, on a reduced scale (about half size), examples similar to those employed in our experiments; they are polished slices or laminæ cut along the radius of a forged ingot. From the figures we see that, in working, these little cavities are elongated in the direction of the axis, and have taken an elliptical form, and that the number of cavities increases as we approach the middle of the ingot.

Fig. 26 shows at *b* the place from which the slices were cut.

II. We will now consider the method of making compact ingots by compressing the liquid steel. The effects of cooling steel which we have observed indicate that we can obtain a cast metal free from bubbles, if we can cast it under a pressure sufficient to hold the contained gas in solution. We may cite here among other examples the proposition of Galy-Cazalat, in 1866, to cast steel under a pressure obtained from powder; also the method of Chaléassiere, in France, where the liquid metal was subjected to a steam pressure of 6 to 10 atmospheres.

These means, although rational in principle, have not been extensively employed on account of the difficulties

Fig. 24.

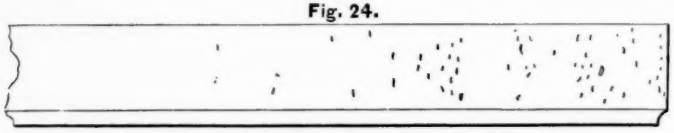
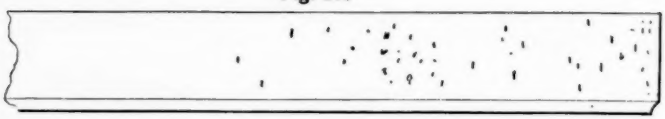


Fig. 25.



encountered in employing them on an extended scale.

It is much more simple to apply a piston directly to the liquid steel when in the mould. As this method of preparing *compressed steel* has been somewhat extensively employed, we will briefly consider it.

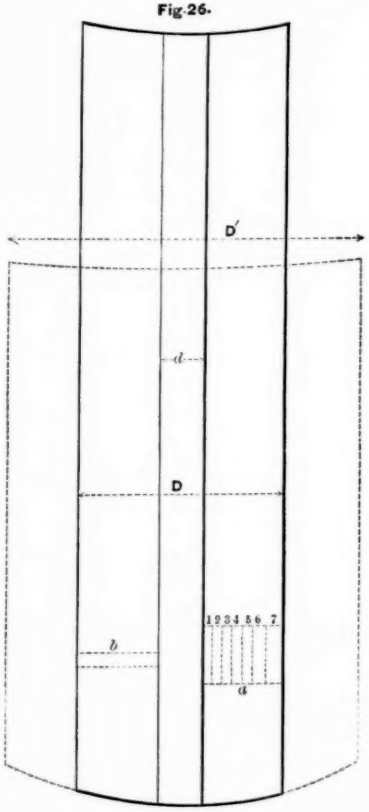
The steel is poured into a mould in the ordinary way, and is immediately subjected to the action of a solid piston worked by a hydrostatic press. The gas, which is partly disengaged, accumulates to some extent around the sides of the mould, by reason of the strong pressure is redissolved.

In order that these bubbles around the sides should be absorbed, it is necessary that the metal here should remain in a liquid condition for as long time as possible. To insure this the sides of the mould are lined with a refractory and non-conducting material. After the introduction of the piston a pressure is exerted, until a sufficiently thick solid crust is formed on all sides to prevent the formation of bubbles. If this were the only object of the use of the piston, only a slight pressure would be necessary, for this would prevent the disengagement of gas. But when it is designed to prevent the formation of the "funnel" arising from shrinkage, a great pressure is required, as the piston is required to follow the contraction of volume until the center solidifies. To accomplish this, Whitworth constructed a press of colossal dimensions. The diameter of the piston was $1^{m}.25$, and the pressure obtained 650 atmospheres;

the piston being urged by a force of 10000 tons.

It is difficult to say to what extent the central shrinkage cavities in large ingots can be prevented by means of such a press; for an ingot exhibited by Whitworth at Paris, cut lengthwise and polished, had a diameter only of $0^m.30$ to $0^m.33$, and a length of $0^m.80$ to 1 meter. At the distance allowed by the

Fig. 26.



glass case the shrinkage cavities could not be detected, and the fracture seemed quite compact.

The compression of liquid steel, notwithstanding its apparent advantages, has not yet been employed in castings, or pieces of complicated form. Moreover, it is known that Whitworth was not content with simply compressing such forms as rings, common bolts and tubes, but that he afterwards subjected them to the steam hammer. Thus, compression alone has not solved in a complete manner the question of casting steel; it has only resulted in the economy of metal arising from saving the upper portion of the ingot. But the results are too costly; the outlay necessary for the press and other accessories, to which is to be added the cost of the labor of compression, is far from being covered by the saving of the metal. For such reasons the application of Whitworth's press remains confined to the establishment of the inventor.

III. We will pass to the third method which differs from the preceding, inasmuch as it has resolved the difficulty in a more complete manner, and rests upon recent theoretical researches.

In the matter of high steel, this problem was solved in part some 20 years since, at the steel works at Durham, under the direction of the engineer Mayer. It was applied to many uses in Germany, Austria and England. Among other objects the bells of Bochum enjoyed and still enjoy a special reputation. Thus far they have manufactured about 3000 bells. It is also known that locomotive driving wheels, steam engine cylinders, propeller wheels, cylinders for hydrostatic presses, gear wheels, etc., etc., have been made at these works.

They made all the objects in moulds of a steel melted in crucibles. The charge is composed in great part of iron rich in silicon. When the means, held for a time secret by the makers, became more or less known, chemical analyses revealed the fact that the compactness of the product was due to the presence of silicon, which yielded a steel free from contained gas. And this for two reasons: at first the silicon diminishes considerably the capacity of the liquid steel for dissolving gas, and further, it prevents the disengagement of the carbonic oxide which is produced by the action upon the carbon of the steel by the oxygen of the ferric oxide dissolved in the steel.

Now, as in fusing in crucibles, the steel is preserved against the oxidizing action of the air, and as its relative hardness diminishes the chances of dissolving the oxide of iron, it follows that the preparation of castings without

bubbles from crucibles does not present such difficulties as arise in the making of mild steels by the Bessemer or Martin process.

If we may judge by the products exhibited at Paris, the manufactory at Terre Noire has conquered the difficulties of casting mild steel free from bubbles.

To the engineers of Terre Noire, under the direction of M. Euverte, is due the credit of having produced on a large scale, ferro-manganese compounds rich in manganese. At present they make this metal containing 80 to 85 per cent. of manganese.

To these gentlemen is due the credit of the new plan of introducing a large quantity of silicon into this alloy, from whence has come the possibility of producing Bessemer or Martin mild steel without bubbles.

It is known that in the Bessemer, Martin or Pernot processes, the silicon contained in the charge is oxidized even at the commencement of the operation and passes into the slag. An exception is presented in the hot process of Bessemer in the case of cast iron rich in silicon. There is nearly always obtained towards the end of the operation a metal free from silicon, and as the spiegel-iron or ferro-manganese contains very little, the steel has hardly any more. Such is the cause of the presence of gas and of oxides in solution in Bessemer and Martin steels, and such is the reason why a greater part of the ingots are full of bubbles. The alloy of ferro silicide of manganese made at Terre Noire, affords a means of introducing into the final product a quantity of silicon, sufficient to dispose of the oxide of carbon and to form a bisilicate of iron and manganese, by the reduction of the oxides of iron contained in the steel.

This bisilicate being liquid and fusible comes pretty soon to the surface, and in this way the metallic bath is relieved entirely of the particles of scoriae which injure the physical properties of the steel.

According to what we learn from M. Pourcel, the new alloy is added at the close of the operation and before casting, in such quantities that the steel, when cast, shall contain 0.2 to 0.3 per cent. of silicon. In order to neutralize the injurious influence of the silicon, it is necessary to introduce a quantity of manganese, such that the ratio between it and the silicon shall be that of their molecular weights; that is, so that

$$Si \times n : Mn \times i :: 3 : 4.5.$$

Steel thus made is cast without ebullition, and yields ingots without bubbles. In order to diminish the cavities of local contraction, they cast the upper part with a waste piece as in iron castings. The beautiful collection of specimens from the Terre Noire works, exhibited at Paris, indicates that the manufacture of steel articles by casting is well-nigh accomplished.

It remains only to reduce the quantity of silicon to be added to the smallest possible amount, in order that not too much manganese shall be required to neutralize it and abstract the carbon from the combination. We may hope to arrive, by this direct method, at a victorious solution of the problem of casting objects in steel.

We will enumerate the articles exhibited at Paris from the Terre Noire Works.

1. Two shells of 32 centimeters' caliber which pierced an armor plate backed by wood to the thickness of a meter. The shells had been fired against the plate at an angle of 20 degrees. The shape of the forward part only was changed. The upsetting along the axis amounted to 14 to 19 millimeters; the entire length of the shells being 787 and 785 millimeters. The enlargement was about .05 millimeter, and the deviation of the point 17.5 to 27 millimeters.

2. A ship cannon of 14 centimeters. The cannon had been examined by the "Commission des Essais Maritime et d'Artillerie" at Ruelle. 100 shots had been fired from it with charges of powder weighing from 4.2 to 4.9 kilograms; the weight of the ball increasing from 18.65 to 21 kilograms. After these experiments it was found that the change of form was less than in a wrought steel gun subjected to similar conditions.

3. A tube which had resisted a trial with powder at Bourges.

4. An ingot of 11½ tons weight for a cannon, roughly turned.

5. Tubes for cannon of 24 to 32 centimeters caliber; a ring for a cannon trun-

nion of 42 centimeters weighing 6½ tons; a connecting rod for a steam engine of 400 horse power; a crank shaft for a locomotive, etc.

All the pieces exhibited from Terre Noire, judging of them after their surfaces were polished, would compare favorably with the best samples of iron. Yet in the fracture of the ingots could be distinguished small cavities of local contraction of which mention has been made above.

In observing the hollow surface of the bubbles, it is noticed that the lower part has a smooth hemispherical contour, and that the sides, especially at the upper part, are covered with dendritic crystals of different forms. (Fig. 27). In comparing carefully these dendrites with the

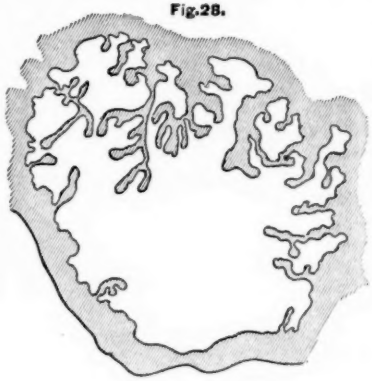
Fig.27.

crystals of the contraction cavities, it is easy to detect a resemblance, and to see that the dendrites are derived from the forming crystals in the steel, as they are in the act of forming at the moment the bubble is arrested in rising to the surface.

The bubble in rising produces a motion in the liquid; a rotation and a separation of the crystals which are floating, but as the crystals have the same temperature as the liquid, they redissolve in it with great facility, so that the bubble of gas, in rising among the crystals, causes some to be partly dissolved; bends some and, forcing them together, causes them to take dentritic forms of the most capricious character, among which it is sometimes nearly impossible to trace a resemblance to the crystals grown in the steel which formed them. (See Fig. 28.) One of these dendrites is represented in figure 29.

It results from this that to destroy the growing crystals, that is to say, to

Fig.28.



redissolve them in the liquid steel, it will suffice to produce a slight motion, for the motion of the bubble in rising is nearly sufficient to accomplish it. This circumstance permits us to conclude that it is possible to break up the prismatic structure of the exterior por-

Fig.29.

tions of steel ingots cast in a metallic mould, and that it is possible also to destroy the local contraction cavities or porosities of the central portion of the ingot.

If then, during the pouring of the steel, a rapid rotation be given to the mould, the crystals which are forming normal to the sides of the mould cannot grow so rapidly as when they are left at rest, and consequently the solidification of the steel would be by united and amorphous layers. If the rotation of the mould be continued, the solidification of the ingot must proceed by layers as united as those near the sides, and as the cause of the local contraction cavities has been removed, the central porosities will be wanting, and the result will be a compact mass which requires neither the press nor the steam hammer. It will suffice to reheat the ingot to destroy the granular structure which it takes on after solidifying, and then to cool slowly. As at the commencement of the casting the growth of the crystals is rapid, owing to the cooling effect of the mould, therefore the rotary motion should be as rapid as possible at the beginning.

It is necessary to observe that as the liquid metal will slowly take up the rotary motion, it will be necessary to reverse the direction of the rotation of the mould quite frequently and suddenly.

For cylindrical ingots which are to be bored through the middle, such as ingots designed for cannons, it is more convenient to rotate them around a horizontal axis, by turning the mould upon its side as soon as a crust covers the surface. For shells widest at the center, the inclined position is preferable. It is certain that by keeping the metal thus in constant motion, homogeneousness is assured.

This method recalls that which has been called centrifugal casting, but the resemblance is only apparent.

In effect, if by the method of centrifugal casting we succeed in obtaining a compact metal, it is due simply to the motion of the liquid which prevents the formation of crystals. But the compactness can only be obtained at the surface, and at the expense of the center. This would be practical in the case of cast chilled rollers, of cannons, cast shot and some articles in bronze, etc., etc.

It remains to consider a question which was raised some ten years ago by my communication upon the structure of steel. "Is it necessary to work the steel even if the casting be compact, that is to say, without local contraction cavities?" In order to reply to this question it will suffice to refer to the experiments of our commission in 1869 (published in Russia in 1870). But I will cite some made more recently. Tables I. and II. suffice to show the inutility of any compression to improve the physical properties of steel. All the difficulties are in casting. The difference in the physical qualities of steel cast and not annealed, compressed or not, and steel annealed and worked, consists in the texture of the grains, in the presence of local contraction spaces, but especially in the granulation. This latter appears to give rise to extensive forces during the cooling from the red heat.

At the commencement of solidification, the exterior portions are subjected to these forces; at the end of it the in-

TABLE I.

EXPERIMENTS UPON TENSILE STRENGTH OF SAMPLES OF STEEL FROM THE TERRE NOIRE WORKS.

Diameter of Sample, 14 Millimeters.
Length of Sample, 100 Millimeters.

Character of Sample.	Elastic Limit, kilos. per sq. centimeter.	Breaking Strain, kilos. per sq centimeter.	Elongation, per cent.	Remarks.
1. Hammered Steel:				
Carbon 0,150	2200	3570	34.0	Containing—Manganese, 0.25%. Silicon, a trace.
" 0,490	2620	4880	24,0	
" 0,709	3160	6800	15,0	
" 0,875	3420	7410	9,5	
Hardened in Oil:				
Carbon 0,150	3280	4680	28,6	
" 0,490	4460	7050	12,0	
" 0,709	6880	10710	4,0	
" 0,875	9050	10600	1,0	
2. Steel Cast only:				
Carbon 0,287	2100	4470	8,8	Containing—Manganese, 0.75%. Silicon, 0.25%.
" 0,454	2650	4330	3,0	
" 0,750	3050	6420	3,5	
" 0,875	3920	6450	1,5	
Hardened in Oil and annealed:				
Carbon 0,287	3160	5180	24,6	
" 0,459	3350	5550	19,2	
" 0,759	3580	7420	14,3	
" 0,875	4609	8260	3,5	

TABLE II.

RESULTS OF EXPERIMENTS UPON THE TENSILE STRENGTH OF STEEL FROM THE WORKS OF OBOUCHOW.

Diameter of Samples, 12,5 Millimeters.
Length of Sample, 150 to 250 Millimeters

Kind of Specimen.	Elastic limit in atmospheres.	Breaking Strain in atmospheres.	Elongation, per cent	Remarks
Eight-inch Shot of Bessemer Steel:				Mean of two analyses.
Not hammered				
Not reheated	2800	6000	4,0	C=0,70; Si=0,07; Mn=0,54.
Reheated	3800	7100	8,0	
Bessemer Steel, worked	2700	6000	16,5	C=0,43; Si=0,04; Mn=0,30.
"	2810	6100	15,5	
Bessemer Steel Ring for a 9-inch Mortar, hammered and annealed				C=0,35; Si=0,01; Mn=0,12.
Mean of several samples	2800	7400	14,0	
An 11-inch Shot from Krupp's Works, hammered	—	6900	10,0	C=0,45; Si=0,01; Mn=0,30
A 9-inch Shot from Terre Noire, annealed,	3800	7100	3,4	C=0,68; Si=0,23; Mn=0,29.
not hammered	4000	8100	5,6	C=0,57; Si=0,24; Mn=0,29.
A 9-inch Shot from Iznoskow, hardened, not worked	5600	5600	0,4	C=0,72; Si=0,22; Mn=0,61.
Steel cast under pressure of 1200 atmospheres, without being worked	2833	4666	2,4	Crucible Steel, containing 0,54 carbon. Mean of 6 samples.
Reheated	3175	5275	6,7	Mean of 4 samples.
Worked and annealed	3200	6400	16,0	Mean of 2 samples.
Steel compressed by 1200 atmospheres				
Worked and annealed	2650	4900	18,1	Mean of 2 samples.

terior portions. Whitworth's method of casting with a core is very disadvantageous, inasmuch as the core prevents the free contraction of an ingot with a hollow center, and there is a force tending to elongate after it solidifies, a condition that leads to granulation. Such is the cause of the low ductility of compressed steel in the form of an annular ingot even after it has been reheated. It appears that Whitworth hammered his steel, which had been already compressed, and it is only in such way that a compressed steel hollow ingot can be made to compare favorably, in physical quality, with the steel of the Terre Noire Works, which has been cast and softened by fire. This is shown by a comparison of Tables I. and II.

From what has been said above it may be concluded that the problem of manufacturing articles in steel by casting in a mould, is now substantially solved, that is to say, with reference to compactness. We obtain this condition by casting very hot, by introducing silicon, or finally by compression under a force of 6 to 10 atmospheres. To give the steel its best structure and the most desirable mechanical qualities, it is sufficient to subject it to a reheating followed by a cooling more or less rapid.

In casting articles in steel especial care is needed to avoid the porosity arising from contraction and the granulated or prismatic structure. The causes of local contraction spaces, as we have observed, may be removed in various ways. According to my theory the motions of the liquid in the solidifying portions should be regarded as of first importance. The employment of moulds of earth; bad conductors of heat; the slow cooling of the steel in the moulds; the absence of obstacles to the free shrinkage of all the parts during cooling, will prevent granulation. By these

means we may avoid the defects in castings.

These conditions may be fulfilled in case of articles of very simple form, by employing an iron mould with thick sides, pierced with numerous holes, and lined with some fine-grained refractory material. This enables us to avoid raising the metal to a very high heat, which is of great importance as regards granulation. Compression by means of a piston has no future, and is of importance only in the most simple forms.

Steam hammers and rollers are indispensable for the manufacture of pieces having such dimensions as to prevent employing the precautions which insure compactness, especially if the surface is to be polished.

FORESTRY IN FRANCE.

From "The Builder."

Considering the great importance of the preservation of forests, and the lamentable want of foresight, which permits their reckless destruction in nearly all parts of the world, but more particularly in our own continent, where forests will soon become scarcer and scarcer unless more practical measures are adopted for their preservation, it is satisfactory to be able to note that some Governments are recognizing the advisability of attempting the preservation of the forests they have under their charge. One of these, we are able to learn from a report published during the late Paris Exhibition, is the Government of France. The document in question, at the time it was issued, did not attract the attention it really deserves, and on that account we refer to it here somewhat fully.

Before proceeding with the report, let us state shortly the extent of forest land in France, as given in *Engels Statistische Correspondenz.* The French forests cover a surface of about 22,688,000 acres, being about 17 per cent. of the total area of France, making her one of the European countries poorest in forest land.

Here it will be of interest to mention that Sweden, of European countries, has still the largest percentage (43 per cent.) of forest-covered soil, notwithstanding the enormous waste that has been going on almost for centuries. Next follow Russia, with 37 per cent.; Bavaria, 32; Austria, 30; the German States (excepting Bavaria and Prussia), 27; Prussia, 23½; Switzerland, 18; France, as above noted, a little over 17 per cent.; Italy, 17; Belgium, 13 to 14; Holland, 7 to 8; Spain, 7; Denmark, 5; and Portugal with 3¼ per cent. Great Britain ranks next to Portugal, having only 4 per cent. of her area covered by forests.

The French forests are very unequally distributed over the country. Leaving out the department of the Seine, which has only 2 per cent. of forest land, the department of the Manche has the least (3 per cent.), while in that of the Landes the proportion is 47 per cent. or nearly half. The forests cover:

		per cent.	
In 18 departments,	below	10	of the soil.
In 42 "	from	10 to 19	"
In 17 "	"	20 to 29	"
In 8 "	"	30 to 39	"
In 2 "	40 per cent. and over of the surface.		

Forests in France are for the most part private property; the Government owning 10.7 per cent., the departments and communes 22.4, public institutions 0.3, and private owners 66.6 per cent. of the forests.

It will be seen, therefore, that the State can do but little directly. The little influence it possessed has gradually decreased. But the law of 1860, to be referred to more fully presently, has somewhat changed this. The Government is now able to prevent the wilful destruction of forests, and to cause the afforestation of waste lands.

Now as to the report to which we have referred. In France the administration of the forests is associated with that of water, under the department styled the "Administration des Eaux et Forets." On the whole, the sphere of its operations is much restricted; forests, as already remarked, are scarce in France;

extensive inundations, on the other hand, are unfortunately of very frequent occurrence in that country.

We learn from the report that a large proportion of forest land does not necessarily exclude a numerous population. Compared with Germany, France has a third less of forest-covered soil, at the same time that she has a population less dense by one-eighth. Belgium, Holland, Denmark, and Great Britain, being either countries with a proportionally large sea coast or else islands, with an especially damp climate, may be left entirely out of the comparison, as they are able to exist without extensive forests. But there is no question that the retrograde process of Spain, her less dense population, is due in no small degree to the absence of forests, more especially as the uniformly mountainous nature of her soil requires, more than any other country, the prevalence of forests. Wherever this test is applied, it will be found (of course, speaking only of European countries) that fertility and density of population are closely connected with the presence of forests. It would form a generous undertaking for any Government to aim at an equalization in this direction. Whatever has been done in this respect in all countries has only been effected piecemeal; consequently it has been of but little influence on the whole. A common mode of procedure is what is wanted.

So also in France. It will be remembered by visitors to the Paris Exhibition that the display made there by the Administration des Eaux et Forets formed one of the most important and instructive collections of that exhibition. The Administration had erected on the slope of the Trocadéro a real palace of wood in the charming Swiss style, to which had been added some outbuildings, among which was a forester's house, constructed of round wood and billets, framework, straw, brushwood, &c. The purpose of the wooden palace was indicated also by products of forestry and tools used in forests fixed to the outer walls and the verandah. The interior formed one large and high hall, in which nothing was wanting that could supply information about French forests. Specimens of the soil and wood of all descriptions, stuffed animals, a beautiful collection of insects and illustrations of their useful or injurious activity, tools of all kinds, a complete library, herbaria, &c., were appropriately arranged, while the surrounding garden grounds contained all the trees and plants of the forest in selected specimens.

The experience gained by the French Office of Woods and Forests with regard to the acclimatization of foreign, especially trans-oceanic forest trees, is particularly valuable. The blue gum tree imported from Australia prospers in the South of France, and by its plantation at the mouth of the Var the marshes surrounding it have been drained, and the fevers formerly prevailing there banished. The trees prosper wonderfully in Algiers, as the section of a trunk not yet fifteen years old, of a diameter of 1 foot proves. But the wood is white, light, breaks easily, and cannot be compared with the durable, solid ship timber which the same tree produces in Australia. The same is the case with the American oak, which prospers in poor soil, grows quickly, and forms beautiful tops of foliage. But the wood is inferior, the bark contains less tannin than that of European oaks. Trees, consequently, can be planted in certain cases only as surrogates, principally to prepare the ground for better kinds. At present, experiments are also being made with the Calfornian theya tree, the wood of which is especially suitable for better classes of furniture; it is doubtful, however, whether its wood will not deteriorate by cultivation in Europe.

But the most important feature of the forest exhibition was the illustration of the planting of trees in places which require afforesting. This includes two very distinct categories, the afforesting of heights and the afforesting of dunes, as well as their turfing, for trees cannot prosper without the growth of grass. On the heights as well as on the sandy shores of the sea, the labors of the forest cultivator meet with unusual obstacles.

The bare lines of hills have, in winter, a superabundance of snow and water, while in summer they suffer from long-tinued drought. By afforesting both evils are to be remedied, but the tree itself suffers most from them. The winds and storms to which the tops of

mountains are exposed, and against which the trees are to protect them, as well as the slopes and the valleys which they form, are also a great drawback to the growth of trees. The forester must consequently apply especial means for attaining his object, the afforestation of lines of hills.

There are many depressions in mountains where the evils indicated are not so pronounced, and some protection against wind and too great drought is found. But the water, or rather the masses of water which are collecting in these depressions when the snow melts, have always sought an exit, and, as they are acting with continuous and, on that account, resistless force, found it. Each depression, each sinking of the soil in mountains, has been formed, long before the existence of man, into channels and gorges, whence in spring enormous bodies of water have precipitated themselves into the plains below, carrying with them masses of stone, earth, and roots. The first step, therefore, is to provide the gorge, which very often has been expanded into a valley, with obstacles against the precipitation of water. Weirs are consequently constructed at suitable distances across it. They either consist of a row of strong piles, the intervals between which are filled up by hurdle-work, or a strong, well-constructed dike is built of blocks of rock. The weirs must be made stronger and multiplied according to the length of the gorge and the quantity of water to be met. They retain the water for some time, which forms by its own action a broad, smooth course, a small lake; all the small stones and dissolved particles of earth settle down, and soon form a broad, deep layer of fertile soil, on which grow first grasses, then bushes, and finally trees. Humidity is here longer preserved by the water kept back, and the edges of the gorge afford some protection against winds and a too powerful sun.

As soon as bushes and trees have risen above the weirs, afforestation proceeds and extends rapidly. More fertile soil and humus accumulate, the gorge is gradually filled up, its slopes and edges become covered with grass, and upon grass follow regularly bush and tree. It becomes possible to lead the water from the weir by a horizontal channel over the edge upon the surface of the mountain, or rather the slope, where then the same series of growth is repeated. The verdure and trees already existing afford protection and supply moisture to the plantations growing on both sides of the filled up gorge. The mountain thus becomes gradually covered with wood from the gorges. The further bush and tree are extending the longer snow and moisture are kept back, the waters rushing towards the gorge decrease, lose in violence, whereby the matter they carry with them is precipitated, and kept back more completely, and, in a corresponding degree, more nourishment conveyed to the plants. The impetuous mountain torrent, which during the short term of its yearly existence only causes mischief and devastation, is gradually tamed, but it flows during a longer period, for the snow retained by the trees no longer melts all at once. The further afforestation advances the further this development proceeds. Finally, the mountain is transformed into a quiet forest brook, which fertilizes the gorge by degrees almost entirely filled up, and never dries up. The mountain covered with forest makes the precipitation of moisture possible; springs break forth, whose waters seek the bed of the old tumbling and plunging torrent.

In the plain, also, this beneficial change makes itself felt. The never failing brook drives mills and machinery; it serves for the irrigation of meadows, fields, and gardens. On the lower slopes, since afforestation has been effected, vineyards, orchards, or fertile, if rugged, fields have sprung up. The afforested mountain protects from cold, excessive humidity, and exceeding aridity alike, but especially also from inundations. It tempers wi ter, cools summer, and prevents especially many of the late night frosts which are so destructive to many of the most fertile plantations.

It is principally mountain chains of medium height where such works are possible as we have here pointed out. But lines of hills of small elevation, or swellings of the ground as we meet them in large plains, exert a similar influence on climate and weather if they are covered by forests. A great many

will, at the present day, smile incredulously when they read how in the Middle Ages vineyards existed in all parts of Northern Germany, and a not inconsiderable trade was carried on with their products. And yet the explanation is as easy and as simple as it can possibly be. At that time nearly the whole country was still covered by large tracts of forest, the winters were consequently somewhat milder, frosts ceasing earlier in spring. As a matter of fact, wherever the vine is cultivated in Germany at the present day, there we find the largest forests. Examples are not rare that as late as this century villages have suffered injury in the cultivation of the vine, or entirely lost it, because forests in the neighborhood have been destroyed. There is no protection in Germany against this wholesale destruction of forests. It is true there is a Ministry of Agriculture, and there are Boards of Health, but there is an absence of legislative enactments for the preservation of forests. It has been repeatedly suggested that existing German forests should be preserved, and, where practicable, schemes of afforestation carried out; at present, however, without any visible effect.

In France the state of the question is in a no more advanced condition. Afforestation proceeds but slowly, and yet France is acknowledged to possess the best law for afforesting mountains. From 1861–77 but 68,000 acres of mountain land were planted with trees, and further 3,700 acres turfed. The sum expended in those seventeen years was only £345,000, really an absurdly small amount for a country which has spent milliards on the improvement of Paris and other similar outlays, and which is on the point of expending other milliards on railways the utility of which is at least problematical. Need we wonder if inundations occur periodically, every time causing injury calculated by hundreds of millions?

The French law of afforestation already referred to, and passed in 1860, orders in its essential provisions that afforestation is to be promoted by public grants of seeds, young trees, money, and other means. Afforesting, if the state of the soil and other conditions make it appear necessary, may be made compulsory. If landed proprietors, communes, and others interested should decline to undertake themselves a regulated system of afforestation, this may be effected by the State, which may take possession for this purpose of the land in question. If persons interested wish, after completed afforestation, to enter again into possession of their soil, and consequently enter upon the enjoyment of the improvements effected by the State, they must repay to the latter the expenses incurred with interest, or cede instead half of the afforested soil. If, notwithstanding this excellent law, proportionately little has been done in France for afforestation, this must be ascribed to the selfishness of the communes and individual persons concerned, which has not been overcome even by the severe trials of inundation. The instability hitherto of the French political system has been suggested as the cause of the little regard paid by prefects and other officials to the subject. It is said that their attention has been so much engrossed by electioneering and other political work that little time is left for undertakings which require years of labor before any tangible result can be shown. We need, therefore, feel no surprise when it has been tried to connect the frequent inundations in France with the carelessness engendered by repeated political changes.

Amongst the relief plans of afforestation effected that were exhibited at the Trocadéro, that of the Torrent du Bourget is the most remarkable. A plan represents the broad, desolate gorge (near the Barcellonnette in the Basses-Alpes) in its state of 1868—everywhere, only naked rocks and sterile tracks of rubble. The hollow has since been half filled up by the construction of powerful high dams of stone. Trees and bushes, as well as the turf, reach in some places as far as the edge of the gorge, while in its middle the former forest torrent has already visibly assumed the quieter, steadier course of a regulated brook. The valley below has never since been visited by the formerly periodically recurring devastating inundations.

The solidification of dunes by means of the growth of grass and the planting of trees offers difficulties of another kind. The question here is to "fix" the sand hills and sand heaps, shifted and

driven about by the waves like balls. The work must be very gradual. A whole series of dunes is marked out, the line being drawn, as near as possible, over their crests. The parting off is effected by means of a strong fencing over the crest of the dunes, towards which smaller cross fences lean herring-bone fashion. The effect of this construction is the accumulation of ever increasing masses of sand in the places thus protected, which eventually form a bulwark for the space behind against the rush of the waves. The area thus enclosed is first planted with meadow grass, and next with coniferous trees, the latter being at first protected against sand drifts by means of brushwood. Sedges, broom, esparto grass also have been employed with advantage for first cultivation. The exhibition contained relief plans of the dune works and plantations of the dunes between the mouths of the Gironde and the Coubre. The soil reclaimed lies partly below the level of the sea, and amounts already to many thousand acres. Where, a hundred years ago, there was only a desolate and marshy expanse, there the eye now ranges over splendid forests, in which deciduous trees begin more and more to show themselves among firs and pines, while prosperous looking villages and large herds of cattle, gardens, and vineyards impart life to a landscape which was formerly a silent and dreary waste.

ON THE VARIATION DUE TO ORTHOGONAL STRAINS IN THE ELASTIC LIMIT IN METALS, AND ON ITS PRACTICAL VALUE AND MORE IMPORTANT APPLICATIONS.

By ROBERT H. THURSTON, A. M. C. E.

From the Transactions of American Society of Civil Engineers.

THE writer has, in various earlier papers, called attention to the important effects of strain in metals in the elevation of the normal elastic limit, and has shown that strain in tension causes in iron a permanent exaltation of that limit, which exaltation may be subsequently taken as a measure of the strain upon which it is consequent; thus overstrain causing accident may be detected by the permanent record so left in the altered character of the metal.

After a long series of experiments and special investigations, the results of which will be found in papers presented at various dates to the American Society of Civil Engineers, the writer fully determined these facts, and confirmation was found in the researches of Beardslee and others. It was also found by the writer that a definite law governed this exaltation of the elastic limit, relating its amount to the time allowed for set to take place, and to the rate of distortion by unintermitted stress. This law was expressed by a formula of the form

$$El = a \log. t + c.$$

in which, though very variable with differing qualitities of metal, for good bridge and cable irons, $a=5$; $c=1.5$; El=per cent.; t= time in hours

The fact was discovered during researches conducted by the writer in the Mechanical Laboratory of the Stevens Institute of Technology, that this same modification of the elastic limit occurs when metals are transversely strained, and this was announced to the American Society of Civil Engineers in a paper presented March 1st, 1876, in which it was shown that in what was called the "iron-class," comprehending both iron and steel, this effect is one of elevation, while, as had been already also shown, on the "tin-class," including the brasses and the bronzes, the effect is to depress the normal elastic limit. Strain-diagrams exhibiting the behavior of the several kinds of metal under these strains, were given as conclusive evidence of the facts presented.

The fact that a permanent distortion of a piece of iron increases its stiffness had been long known. Bell-hangers had, from some unknown but very early date, been in the habit of stiffening wire and

guarding against subsequent stretching while in use, by straining it considerably before putting it in place. As early as 1850 Clarke remarked, ". . . if the compressed and extended portions of a wrought iron bar could be, by any artificial means, permanently strained previously to its employment as a beam, such a beam would deflect less than a new bar, and would be practically a stronger beam, since the strength is regulated solely by the bending of the bar."

This idea was also practically applied in 1854 by Werder, at Munich, who stiffened his rods before placing them in the structure, by giving each a permanent extension by tensile stress exceeding the primitive elastic limit. Neither of these, nor the later experiments of Bauschinger (1873) and others, led to the discovery of the elevation of the normal parabolic curve of successive elastic limits, *per saltum*, as finally discovered by the writer, and corroborated by Beardslee; but the increased stiffness noted was attributed to that general, normal, and invariably regular, elevation of the limit by increasing strain, which is seen in all cases and with all materials, and which produces a smooth and usually parabolic strain-diagram.

The writer has now noted and brought to the attention of engineers the fact that the exaltation of the normal elastic limit due to any given degree of distortion in the "iron-class," and its depression in the "tin-class," occurs under intermitted strain, whether the stress be applied longitudinally, transversely, or by torsion, and has presented experimental data proving this phenomenon to thus occur, and experimental quantitative determinations of the law of its variation with time, and the amount of such variation.

He has now to present still another interesting and probably important phenomenon of similar character.

It seemed probable that, if strain in either direction, when exceeding the elastic limit, always produces variation of the normal position of that limit, this effect must be due to a general modification of molecular relations, that should modify the effect of the force of cohesion in other directions than that in which the strain had been given. An investigation was made, and this matter was experimentally studied, as opportunity permitted, in the Mechanical Laboratory of the Stevens Institute of Technology, until sufficient data was accumulated to give conclusive determinations.

Iron and steel wires broken by tension were found to have the transverse elastic limit abnormally elevated, and to have become very stiff and of comparatively slight ductility. This was true of wires of other metals, and of heavier sections of metal. A large quantity of cold-rolled shafting of all sizes, of which both the longitudinal and the transverse dimensions had been altered by rolling cold, exhibited great increase of stiffness and strength, and an even more considerable exaltation of the normal elastic limit. Torsion similarly stiffened wires and rods longitudinally, and test pieces longitudinally strained, become stiffer against torsionally and transversely applied stress. Thus, orthogonal strains mutually affect orthogonal resistance of metals; and the engineer is, by this fact, compelled to study these mutual influences in designing structures in which the stresses approach or exceed, separately, or in combination, the normal *primitive* elastic limit of his material.

The following is, in detail, an account of the behavior of a bar of "good merchant iron," under the action of intermittent and successively applied orthogonal strain (transverse succeeded by tension):

A bar of good bridge or cable iron 2 inches square and about 4 feet long was split longitudinally; one-half was cut into tension test pieces, and the other half bent on the transverse testing machine to an angle at the middle of about 120 degrees; the bent bar was then cut into tension test pieces like the first, and finally all these pieces were broken in tension.

On examining the results thus obtained it was found that the original elastic limit of the metal, as exhibited by the test of the unbent bar, had been exalted by transverse strain in all parts of the bar which had been so strained before being tested by tension. This elevation of the primitive normal limit had not occurred, as would have been expected, to the greatest extent at the points most strained—*i. e.*, nearest the bend at the middle of the strained bar—

and less and less as the point of maximum strain was departed from, until, at the ends of the bar, this elevation became much less observable; but it took place irregularly, and, on the average, about as much at one part as at another.

The following are the figures obtained (the bent bar was cut into eight and the unbent into six pieces, and numbered consecutively from end to end):

I.—Effect of Transverse Strain on the Tensile Elastic Limit.

(Elastic limit in pounds per square inch, and kilograms per square millimeter.)

Unbent Bar.			Bar Strained by Bending.		
	Kg. per sq. m.m.	Lbs. per sq. in.		Kg. per sq. m.m.	Lbs. per sq. in.
No. 1	16.3	23 300	No. 1^1	21.6	30 900
" 2	16.7	23 800	" 2^1	23.5	33 500
" 3	16.9	24 100	" 3^1	18.2	26 000
" 4	16.4	23 400	" 4^1	19.6	28 000
" 5	14.6	20 800	" 5^1	22.4	32 000
" 6	15.7	22 400	" 6^1	19.6	28 000
			" 7^1	22 4	32 000
			" 8^1	19.8	28 200
Average	16.1	22 967	Average	20.9	29 825

The elevation of the primitive elastic limit, in this instance, is thus seen to have been 30 per cent., as an average, and in some parts of the bar about 50 per cent. The new series of the elastic limits are seen to be less uniform in value than in the original bar; but, comparing adjacent pieces, in no case is the elevation of the limit less than 1 ton on the square inch, and it usually amounts to more than double that figure. Singularly, also, the greatest change has been produced farthest from the middle, and the least at that point (Nos. 1 and 6, at the ends of the unbent bar, correspond to 1 and 8 of the other; and 3 and 4 of the first and 4 and 5 of the latter correspond, both pairs being from the middle). It should be observed that the quality of the bar tested, although good as metal of that size runs in the market, is not high, and is not as regular as it should be. It is a "50,000 pound iron."

But the transverse strain here produced, and which is seen to have so greatly modified the primitive elastic limit of the metal, had not materially or even observably affected its ultimate tenacity; this is seen by a comparison of the results of tests *to* the point of fracture, thus:

II.—Effect of Transverse Strain on Ultimate Tenacity.

(Tenacity in pounds per square inch, and kilograms per square millimeter.)

Unbent Bar.			Bar Strained by Bending.		
	Kg. per sq. m.m.	Lbs. per sq. in.		Kg. per sq. m.m.	Lbs. per sq. in.
No. 1	40.9	58 450	No. 1^1	34.1	48 700
" 2	34.5	49 330	" 2^1	34.7	49 500
" 3	35.4	50 520	" 3^1	33.5	47 900
" 4	35.6	50 980	" 4^1	37.5	53 600
" 5	36.8	52 540	" 5^1	36.4	52 000
" 6	30.1	42 980	" 6^1	36.8	52 600
			" 7^1	36.2	51 700
			" 8^1	33.4	47 700
Average	35.6	50 800	Average	35.3	50 475

It is seen that the two averages are as nearly identical in value as could be expected, and that the average ultimate resistance to rupture was apparently not altered by the straining due to transverse stress.

Yet, noting the difference of the figures for adjacent parts of the two stripes into which the original bar was split, we may make an interesting comparison, thus:

(We compare No. 3 with No. 4_1 and No. 4 with 5_1, because the middle of the bar falls, in the one case, between 3 and 4, and in the other, between 4_1 and 5_1.)

On examination of these figures we are struck by their irregularity, by the fact that the greatest changes both of elastic limit and of tenacity are produced at the ends of the bar, and by the singular phenomenon of an apparent *decrease* of tenacity at one of the ends

III.—Effect of Transverse Strain in Elevating the Primitive Elastic Limit and Ultimate Tenacity.

(Differences by comparing Tables I and II.)

	Elevation of Elastic Limit.		Increase of Ultimate Tenacity.	
	Kg. per sq. m. m.	Lbs. per sq. inch.	Kg. per sq. m. m.	Lbs. per sq. inch.
No. 1_1 No. 1	5.3	+ 7 600	− 6.8	− 9 700
" 2_1 " 1	4 1	+10 200	− 6.3	− 8 950
" 3_1 " 2	1.6	+ 2 200	− 1.0	− 1 430
" 4_1 " 3	2.2	+ 3 900	2..2	+ 3 080
" 5_1 " 4	6.0	+ 8 600	0.7	+ 1 020
" 6_1 " 5	5.0	+ 7 200	0.1	+ 160
" 7_1 " 6	6.7	+ 9 600	6.1	+ 8 720
" 8_1 " 6	4.1	+ 5 800	3.3	+ 4 720

of the bar. It seems improbable, however, that the latter effect can have been consequent upon any deformation of the bar; it may be more probably attributable to local defect in that end of the strained strip, due to cinder streaks. From the irregularity noted it seems evident that good iron, so called, may possess—as indeed inspection usually indicates—great local defects.

Again, bars of iron were subjected to severe lateral compression, increasing their length and decreasing their cross section about 15 per cent.; then testing the metal by longitudinal strain, *i. e.*, by orthogonal stress, the writer obtained the following average figures. (See table below.)

Thus it is seen that lateral compression to this moderate extent may elevate the longitudinal elastic limit nearly 100 per cent., may increase the longitudinal tenacity 33 per cent., and may raise the modulus of elasticity 4 per cent., while decreasing the ductility in the orthogonal direction 60 per cent.

Tests by Tension after Lateral Compression.

Elastic Limit.		Tenacity per Unit of Area.				Extension.	Modulus of Elasticity.
		Original Section.		Fractured Area.			
Lbs. on sq. inch.	Kg. per sq. m.m.	Lbs. per sq. in.	Kg. per sq. m.m.	Llbs. per sq. in.	Kg. per Sq m.m.	Per cent.	Lbs. on sq. inch.
Unstrained bar...30 000	21	52 500	36 5	89 870	64	24.6	25 270 750
Strained bar 59 000	42	69 000	49.	105 600	75	10.4	26 230 500

A similar experimental determination of the effect of equal lateral compression on resistance to flexure gave the following figures:

FLEXURE AFTER LATERAL COMPRESSION.

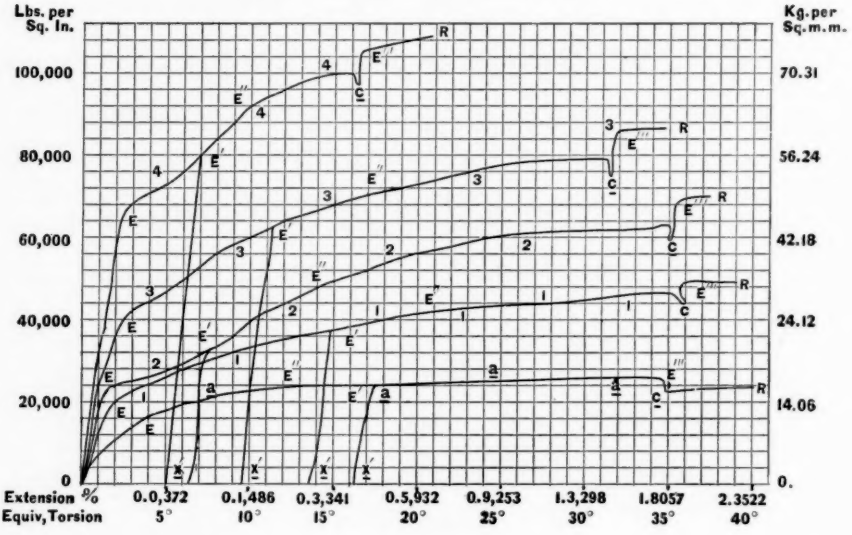
Cylindrical Bars 1⅛ in. diameter x 40 in. between supports (2.8 c. m. x 1 m.)

Load at Elastic Limit.		Modulus Elasticity.	Max Load.		Resilience at Max. Deflection.	
Lbs.	Kilog.	Lbs. per sq. inch.	Lbs.	Kilog.	Ft. Lbs.	Kg. m.
Unstrained bar...1217	553	27 174 500	1870	850	552	76.5
Strained bar 2700	1227	25 691 500	3395	1543	1049	145.

Thus lateral compression to the extent here practiced increased the elastic limit in flexure more than 100 per cent., *reduces* the modulus of elasticity as estimated from flexure 6 per cent., increases the maximum resistance 90 per cent., and nearly doubles the resilience at maximum deflection (4 in. 0.1m).

From the fact that the changes produced by cross-bending are felt in internal strain ocurring, not simply near the point of flexure, but throughout the whole extent of the beam flexed, it would seem that shearing strains are more serious and general than we have hitherto supposed. This latter is a matter of importance in determining a correct theory of transverse strain, and the subject is undoubtedly deserving of extended and careful investigation with a view to discovering precisely the nature and intensity of such strains under all usual conditions in all the materials of engineering construction—first feeling out these strains in the manner here indicated, and then work

FAC-SIMILE AUTOGRAPHIC STRAIN DIAGRAMS.



ing up the details of the theory until a complete and satisfactory analyses is attained.

Conclusions.—We may now summarize the results of the study of this subject, so far as the writer has yet presented them, and the conclusions to which he has been conducted.

In the annexed figure, let 1 1 1 1 represent the strain-diagram of a soft, malleable (wrought) iron, like Swedish or Norway; let 2 2 2 2 be that of a good common merchant iron of small size; let 3 3 3 3 be the diagram of a mild, and 4 4 4 4 that of a tool steel; while, in contrast to these examples of the "iron-class," let *a a a a* be the strain-diagram of a metal of the "tin-class;" for example, a ductile brass or bronze.

When these metals are strained, they are always found to exhibit a gradually increasing resistance pretty nearly proportional to the extent of change of shape, until a point, E, is reached, when the rate of increase of extension becomes greater—usually very much greater—and the deformation remains permanent when the piece is unloaded, and very nearly equal to the distortion under the load. The removal of the load then, if it is not renewed, gives a strain-diagram O, E, E_1, x_1, the distortion being permanent at x_1. This is the natural or "normal" curve, and it exhibits the normal and long known form of elevation of elastic limit. At the last moment, when the load and distortion are measured by the ordinate and the abscissa, respectively, of the point E_1, the elastic limit has become a maximum. Had the piece strained broken at E_1 the limit of its elasticity would have become identical with the limit of strength and point of rupture, and its measure would have become identical with the modulus of rupture; for, considering the piece as unbroken at this point, the distorted piece would have for its strain-diagram the straight line E_1, x_1, and would have now been broken when loaded, at the moment that the stress attained the magnitude measured by the vertical let fall from E_1 to the base line. The point E on each diagram marks what is usually known as the Elastic Limit. To distinguish this from the successive limits of elasticity which are due to permanent successively increasing strains, the writer has called the natural and original apparent limit of elasticity, E, the "*Primitive Elastic Limit*," and any other points, E_1, E_{11}, in a smooth curve representing a strain-diagram exhibiting the effect produced by unintermitted and regular distortion, the "*Normal Elastic Limit*" of the piece when in such condition of deformation, the whole curve being, as has been stated, a "*Curve of the Loci of successive Elastic Limits.*"

This normal elevation of the elastic limit, therefore, as strain progresses and permanent deformation increases, occurs regularly, and the strain-diagram takes the form of a smooth curve such as has been long known to represent it, and such as will be found in Morin's "Resistance des Matériaux" and other works published during the last quarter century.

But, instead of producing a regularly increasing deformation by regularly increasing stress, let load be steadily added until at some point E_{111}, corresponding to a distortion O, E_{111}, further addition of load ceases, and the piece remains permanently distorted. The metal now gradually yields, and there occurs a depression, *c*, of the elastic limit, which in the iron-class soon reaches a limit, but in the tin-class, if the load be not wholly or partly removed, may continue until rupture or maximum possible deformation takes place. Now, renewing the stress, it is invariably observed that this depression of elasticity is, in the case of the iron-class, only apparent; for the extension of the strain-diagram now takes place at a higher range, E_{111} R, and we observe at E_{111} that phenomenon of "Exaltation of the Normal Elastic Limits" which has been studied by the writer, as seen at E_{111} in curves 1, 2, 3 and 4, and which has until recently been unnoticed by authorities.

Making the same experiment on metals of the tin-class, we usually observe the depression of the normal succession of elastic limits which distinguishes this class from the first, as at E_{111} in *a a a a*, sometimes, however, this depression is unobservable.

This distiction between the two kinds of metals has been shown to have peculiar importance in its bearing upon the permissible values of the factor of safety in structures of metal, the value allowable in constructing in iron or steel being

lower, and that demanded in parts composed of the second class of metals being higher than would be proper except for this singular characteristic.

Studying the effect of rapidity of distortion, we find that in the case of the iron-class greater rapidity of distortion causes a decreased resistance, and that a slowly produced deformation causes relatively higher resistance, while the opposite is the case with metals of the second-class. We see that the rate of set is also related to the time allowed for it. It thus happens that with the same metals strained at such a rate as to give a strain-diagram **1111**, an accelerated distortion may produce the diagram **2222** or the diagram *aaaa*, accordingly as the metal is of the first or second class.

Still further, it has been shown in the earlier part of this paper that the exaltation of the elastic limit in iron, &c., is not confined to the direction of the strain produced, but that it affects the metal in such manner as to give it an exalted elastic limit with respect to all subsequent strains however applied. Thus, the engineer may make use of any method of strain that he desires, or that he may find convenient, to secure the condition of increased stiffness that he may desire in any given direction. He may strain his bars in tension to secure stiffness in either tension, compression or transversely, or he may give his bars a transverse set to obtain a higher elasticity in all orthogonal directions, or he may compress the metal, as by cold-rolling, and thus secure enhanced stiffness and elasticity in either longitudinal or transverse directions.

Finally, the writer having shown that the exalted elastic limit being a permanent and determinable effect of any strain which exceeds the "primitive elastic limit," it must remain a permanent and ineffacable record of the maximum load borne by the metal; this fact is seen to be of inestimable importance, as it enables the engineer to trace such distribution of strain as may have occurred in a wrecked structure, to determine the location of defective and flawed pieces, and to ascertain the distribution of strains generally, whether in structures or in single members.

This last suggestion may, perhaps, prove of more value to the profession than that relating to the increased safety due to this exaltation of the normal limit of elasticity. The value of this method of investigating experimentally the distribution of stress with a view to determining a correct theory of resistance of materials and of stress, is also probably obvious to every student of the imperfect and largely hypothetical mathematical method of treatment of the subject now usual.

These practical, readily applicable and exceptionably important facts, seen to be derivable from a careful and intelligent study of the position and of the method and extent of Variation of the Elastic Limit in metal, whether in single masses exposed to strain, or in structures, lend full confirmation to the remarks of the writer before the American Society of Civil Engineers, when first presenting this need of studying the elastic limit more carefully even than the ultimate resistance of metal.

"In determining the value of materials of construction, it is usually more necessary to ascertain the position of the limit of elasticity and the behavior of the metal within that limit, than to determine ultimate strength, or except, perhaps, for machinery, even the resilience. The fact is becoming recognized that it should be possible to test every piece of material which goes into an important structure, and *to then use it* with confidence that it has been proven to be capable of carrying its load with a sufficient and known margin of safety. . . . The method here described" (by use of the Autographic Testing Machine) "allows of this practice with perfect safety. The limit of elasticity occurs within the first two or three degrees, and as seen, the standard specimen may be twisted a hundred or even sometimes two hundred times as far without even reaching its maximum resistance, and often far more than this before actual fracture commences. It is perfectly safe, therefore, to test, for example, a bridge rod up to its elastic limit, and then to place it in the structure with a certainty that its capacity for bearing strain without injury has been determined, and that formerly existing internal strain has been relieved. The autographic record of the test would be

filed away and could at any time be produced in court as evidence—like the 'indicator diagram' of a steam engine—should any question arise as to the liability of the builder for any accident, or as to the good faith displayed in fulfilling the terms of his contract."

We now see that beyond all this lies open to the engineer a wide and important field of study, and that in the knowledge attainable by an investigation of the characteristics of the metal used in construction, as revealed to him by its behavior far within the limit of final or even incipient rupture, and as pictured in the strain diagram, he may find precisely that knowledge which is most essential to him where either economy or safety is of primary importance.

The subject is only just beginning to secure the attention that its importance demands, but it is to be hoped and fully anticipated that we may soon learn much more in relation to it, and that engineers will ere long make daily application of facts now discovered and of methods already made familiar to them.

IRRIGATION IN CEYLON.

By HENRY BYRNE, M. Inst. C. E.

From Selected Papers of the Institution of Civil Engineers.

THE circumstances of Ceylon, as regards the benefits of irrigation and the methods of practising it, are so similar to those of India, that, in view of how thoroughly the subject has been treated in the papers relating to Indian irrigation in the Proceedings, some apology is needed for any remarks in reference to the smaller of the two countries.

Three different methods of obtaining water for irrigation are practised in the Island: 1st. Raising it by manual labor from wells and ponds; 2nd. Collecting it in tanks fed by the drainage of the neighborhood; and 3rd. Tapping the mountain streams and torrents.

The first of these is adopted in the small densely-peopled district at the extreme north of the island, known as the Jaffna Peninsula, and in a few other places where the country is so uniformly flat as to present no site for tanks of the ordinary Indian type, and where there is no river or other natural source of fresh-water supply but the direct one of the periodical rains. Garden cultivation is, however, the only one to which the system of irrigation from wells is applicable; because it alone is sufficiently profitable to pay for the labor involved, and because less water is required for it than for the cultivation of rice. Rice is certainly grown in the district, but to a very small extent, and only where the lands are unfit for other purposes; for a successful rice harvest there depends upon the rainfall, which is very uncertain, and upon the ponds, which often fail, but which, when full, yield a supply of water in aid of the rains. The water is raised from these ponds by a scoop swung from a rude scaffolding, and worked by two, four, or six men. The country lies at a level generally less than 10 feet above the sea. The wells are sunk to a depth of 15 or 20 feet through the magnesian limestone, which almost everywhere underlies the soil within 2 or 3 feet of the surface; and, except for a few days in the year when heavy rain falls, they are supplied by percolation from the sea, the water being freed from salt by contact with the limestone and other mineral substances in its slow passage to the wells. As may be readily supposed, wells thus filled are soon emptied; and in fact the supply is generally exhausted when a well has been drawn upon for a few hours; and from twelve to sixteen hours elapse before the supply is renewed. The mode of raising the water is by a lever, 20 to 30 feet in length, turning on an axle resting on two uprights, and having a bucket suspended by a rope or light pole from one end, which is lowered and raised by hand, the lever being weighted at the other end so as to counterbalance the filled bucket and facilitate the raising of it. When the well is deep and the lever long in proportion, the work is further aided by a man, and in some

cases two men, walking backwards and forwards on the lever, so as to contribute by their weight at the two ends alternately to the rapid rise and fall of the bucket. In this way about 600 cubic feet of water may easily be raised from a single well in one hour. On an average one well is sufficient for the irrigation of an acre of garden land in the driest weather where the soil is light, and of an acre and a quarter where the soil is less absorbent. As these wells never fail, being supplied from a source which is independent of rainfall, the successful raising of two, and even three crops, in the year from the same land is as much a matter of certainty as the recurrence of the seasons.

Those parts of the country where the system of tank irrigation prevails surround the district lying within what is called the Mountain Zone, and extend to within a few miles of the coast, embracing about three fourths of the area of the island, and having an elevation of from 20 to 100 feet above the sea. For the most part the rivers intersecting these low-lying districts are dry for ten or eleven months in the year; but in January and June, when heavy rains fall, they overflow their banks, and inundate a wide stretch of country on each side. In a few instances only was any attempt made in former times to utilize them as feeders of tanks, by throwing weirs across them in order to divert the water by canals to the desired storage ground. The general practice was to depend for the filling of each tank upon the rainfall within the limited area selected as the site for it. As the country is undulating, it affords thousands of sites where tanks could be formed by damming up the outlets of drainage basins. The early conquerors of the island, who (about five centuries before the Christian era) introduced into it the arts then known in India, recognized these natural advantages, and availed themselves of them—as did their successors for more than a thousand years—to cover the face of the country with tanks, mostly of large size, some few forming lakes of from 20 to 50 square miles in extent, having embankments or "bunds" of 10 to 15 miles in length, and capable of irrigating tracts of land as large as Middlesex. All were constructed on the same model, made familiar by the papers on Indian irrigation read before the Institution from time to time, an earthen embankment being made across the lower end of a drainage basin, such embankment being pitched on the upper side with rough stone, and having at one end or at both ends an overfall for the discharge of flood waters, and sluices of elaborate construction for distributing the water to the fields below.

But all these great works were destroyed in succession, perhaps soon after their construction, owing to inadequate provision in the length of the overflow, and to the difference in height between it and the bund, to meet the case of an extraordinary flood. This need not be a matter for surprise; for, even had the designers of these tanks possessed that knowledge of hydraulics which would have enabled them to adjust the length of an overflow to the discharge of a given body of water in a given time, they had no means of ascertaining the quantity to be discharged. The rain gauge was unknown to them; and it is certain that the country was then covered, as it still is, with a jungle so impenetrable that nothing more could be known than the bare fact, that by throwing an embankment across the low land between two hills of moderate elevation, a reservoir might be formed of capacity presumably large enough for the purpose intended. Only those perhaps who, like the author, have had occasion to lay out works of this kind in such a country, can form an adequate conception of the difficulty of arriving at data sufficiently reliable for the design of such a bund and overfall as would be safe under all circumstances. There are no maps, like the ordnance maps of Great Britain, from which the area of any drainage basin can be ascertained; and the cost and labor of making a special survey for the purpose in any given case would be enormous. Then, observations of rainfall have not extended over a sufficiently long period to show what ought to be taken into account in designing works of this nature; nor have they, owing to the want of intelligent observers, been carried out in all the most desirable localities. Thus, a rainfall 10 or 12 inches in

depth in one day—a thing of almost annual occurrence in some locality or another—had till lately been commonly accepted as the limit of what was probable anywhere; but in 1872 there was registered at one station a fall of 18.9 inches, and at another a fall of 17.9 inches, in twenty-four hours.

In view then of the difficulty of obtaining correct information on the two essential points of area and rainfall, it would almost seem that no work of this kind can be safe for any considerable length of time, unless the dam to retain the water be of masonry throughout, so as to form one continuous overfall from end to end; or, at least, the usual condition of things being reversed, and the length of the overfall, instead of being the smaller, be made by much the larger fraction of the whole length of the structure. The author's impression to this effect has been strengthened by what occurred recently to several tanks of moderate size in the eastern province of the island, restored or reconstructed only a few years ago, on designs based upon calculations which were believed to be perfectly safe. In the case of one of them, which may be taken as a fair sample of all, the overfall was of extraordinary length as compared with the bund, and it was believed that not more than 2½ feet depth of water could ever rise over it, while the top of the bund was from 6 to 7 feet above the estimated flood level. It seemed to the author, who saw it several years ago, that the great length of the overfall afforded ample provision against all possible accidents. But in January, 1878, the rainfall throughout the district was heavier than had been experienced for many years, giving rise to floods which carried away numbers of bridges and other works, and raising the level of the water in this particular tank to nearly 9 feet above the overfall, or just sufficient to overtop the bund and carry away a large portion of it.

Smaller tanks adapted for the irrigation of from 20 to 200 acres, which are most numerous in the northern and north-central provinces, and are the only structures of the kind now in use there, were formed in a much ruder manner than that followed in constructing the magnificent works which have fallen to ruin. They probably owe their existence to the small village communities, into which the population was divided on the failure and abandonment of the larger tanks, and when the country no longer possessed to any extent the skilled labor which the native kings had called into play when carrying out those immense works. In none of the hundreds of tanks which have come under the author's observation was there, until quite lately, anything deserving to be called a work of art. The overfalls were, in most cases, merely a depression in the bund, protected sometimes by rough stone pitching, or they were scarped out of the hard ground against which the bund abutted; while the sluices were formed of undressed blocks or slabs of stone, and often merely of rough timber, without any better means of stopping the flow of water through them than a gate of wattles banked up with turf, which the cultivators removed when they desired to let the water through. That structures so rude should have lasted through so many ages, can be due only to the ease with which any damage to them might be made good by the villagers. But neglect on their part has so often led to damage beyond their power to repair, resulting in the stoppage of cultivation for two or three years in succession, that the Government, in the interests of the people as well as of the revenue, felt bound to step in by legislation which placed the management of these tanks, and of small irrigation works generally, on a proper footing, and removed all excuse for that neglect into which they were gradually falling. Under this improved system, small works of restoration and repair are now carried out in all parts of the country, with skilled labor employed under Government supervision, and with a happier result than would probably have followed the realization of those grand schemes, so often proposed, of restoring the larger works abandoned centuries ago, to bring which into operation would necessitate the introduction of a new population.

Of the exceptional class of works already alluded to, where the design was to dam up the water of a river and divert it by a channel to a tank, the most remarkable is the Giant's tank, in

the northern province, of the date of construction of which there is not even a tradition. In this case, the mistake committed was more unaccountable than that which caused the destruction of the ancient tanks; for the nature of the country in which it is situated must have been easy to study, being a dead flat and generally open, the soil being incapable of supporting the luxuriant growth of jungle which renders other districts so difficult to explore. The dam, or "anicut," across the river was formed of large rectangular blocks of roughly-dressed stone, so well put together that it is still in as good order as when it left the masons' hands. The tank on the right bank of the river, some few miles below the anicut, formed by an earthen bund several miles in length, but nowhere more than about 10 feet high, was nearly completed, and a similar tank on the opposite bank in part constructed, before it was discovered that the bed of each was at too high a level for the water to reach it; and that both tanks, even had it been possible to fill them, must have been so shallow, that evaporation would not have left in them a month's supply of water for the area designed to be irrigated.

In the district of Karetchi, near the neck of the Jaffna Peninsula, the rice fields lie in several large patches on each side of one of those rivers which flow only at intervals when there is heavy rain. Like the fields in the peninsula, they are mainly dependent upon the direct rainfall, and upon the ponds which lie scattered amongst them. Although it was ascertained, by a survey which the author made in 1858, that a tank sufficiently large to irrigate them abundantly might easily be formed a few miles higher up, it was not considered that the work would be remunerative, in view of the cheap rate at which rice could be imported from India; and the project of carrying out the work was therefore abandoned. But the people endeavor to supplement the scanty supply of water derived from the rains, by throwing out temporary groynes of timber and earth from each bank of the river just before an expected flood, to divert a portion of the flood waters by channels leading directly to their fields. When the floods are moderate these groynes do a good service for a few weeks; but as often as not they are carried away. To check the tendency to erosion, by diminishing the velocity of water in them, the channels are made so tortuous, that their actual length is more than double what they would be if straight, and they are otherwise so badly formed that much of the small supply of water yielded by the river is wasted.

The third method of obtaining irrigation is practised in the mountainous districts by tapping the streams. The fields are numerous, but nowhere so extensive as those commonly met with in the low country. For the largest of them a channel six feet wide and about two feet deep, conveys all the water necessary for thorough irrigation; and to divert along it as much water as may be required, nothing more is needed in most cases, than to throw a few boulders into the stream just below the point from which the channel commences. In those few cases where, during dry weather, it is necessary to prevent any waste of the water brought down by the stream, there are properly constructed stone dams with regulating sluices. The channels are scarped out of the hillside, following the contour of the ground, and for a short distance after leaving the stream they are protected by a low wall on one side, which acts as an overfall whenever an undue quantity of water is discharged into them, as happens when the rains swell each stream into a torrent.

None of the irrigation channels in Ceylon are large enough to be used for inland navigation; and for this reason they have been everywhere laid out with as great a rate of fall as is consistent with a view to safety against silting. For the most part their inclination gives a velocity of water of from two to three feet per second; but even where the velocity reaches four feet per second, as it often does, there is no appreciable erosion of the sides or bed. Much, of course, depends upon the character of the soil through which the channel may be cut. But, so far as the Author's experience goes, the lightest soil will bear a velocity of two feet per second, where the sides of the channel have a slope of two to one; while in stiff clay soils, a slope of even one to one is ample in the most rapid of these channels. Such an

assertion may, no doubt, appear inconsistent with what is commonly set down in printed rules and tables as to the moving power of water at given velocities; but these rules, however valuable as a general guide, are based upon experiments tried under conditions which never, or but rarely, prevail in actual practice. The Author has generally found that silting (in the case of channels cut on a contour line in sidelong ground) is due not to the diminished velocity of the stream, but to the surface drainage from the land on the upper side of the channel. Yet even here the close vegetation above is usually sufficient to prevent the surface soil from being carried into the channel; and in the worst conceivable case, where the land above is bare and the soil loose, a catchwater drain above the channel, with frequent outlets under it, would be an effectual protection.

In no case has the Author found any tendency to the excessive growth of weeds in channels having an appreciable fall. It is in canals intended for navigation only, and where there is no current, that he has experienced any trouble in keeping down such vegetation; and a little attention on the part of the native overseers is sufficient for this. A small force of men is usually kept on a line of canal to prevent cattle from injuring the banks; and these men are provided with rakes, by which the weeds can be torn up and drawn to the banks as fast as they appear. Moreover, it is only in shallow canals used for flat-bottomed boats, where the depth of water never exceeds four feet in dry weather, that weeds are likely to spring up to any extent; and in these men can easily wade while working the rakes, if the canal be too wide for the weeds to be reached from the bank. The experiment of attaching large rakes to the stern of a boat drawn along a canal, in the hope of economizing labor by a wholesale system of weeding, had a fair trial; but the primitive method of raking by hand was found to be as efficient, and much more economical.

The Author regrets that he cannot give any details of cost of the various irrigation works undertaken in Ceylon in recent times. Such details would be of little interest, except in connection with a statement of results as to the quantity of water made available, and the extent of land brought under tillage in each case; and trustworthy information on these points is not procurable. Enough is known, however, to prove that in Ceylon generally, and especially in the unhealthy districts, where tank irrigation is chiefly carried on, the high price of labor must always render new works too costly to be commercially profitable. For this reason attention has of late years been confined to the improvement and restoration of small works long existing, but which had either been badly constructed originally, or had been suffered to fall into neglect, and where the cost of restoration, though often great for the small amount of work done, is trifling in comparison with the benefit obtained. By the outlay incurred, lands which had for many years lain fallow are now brought under cultivation; and the cultivators are no longer dependent for food upon imported grain, the price of which, however low at the sea-ports, is increased enormously by transport to the interior.

LIGHTHOUSE CHARACTERISTICS.

From "The Architect."

In March 1873 an article on "The Lighthouses of the Future" by Sir William Thomson, the Professor of Natural Philosophy in Glasgow University, was published in one of the periodicals. It suggested the introduction of a system of flashing resembling the Morse system employed in telegraphy, and the use of a uniform arrangement of bright lights, to be known from each other by the number and length of times they appear between intervals of darkness, instead of the existing fixed, revolving, flashing and colored lights. Each lighthouse was to be distinguished by a letter, and the light would appear in view, disappear, and reappear for a number of seconds that should correspond with the dashes

of the Morse alphabet. The plan by which the signals were to be carried out was simple. One large Argand lamp was to be fitted in the center of the light room, around it a metal band was to rise and fall with clock-work, obscuring the light at the proper intervals; or, secondly, a large spherical screen was to be moved round the lamp outside the great dioptric lenses, having slits in it from top to bottom, to allow the light to pass through at proper intervals, or by burning gas instead of oil, and lowering and raising the flame at the proper intervals by means of a water stop-cock, a small "by-pass" being connected to supply as much gas always as would prevent the flame from going out. The new scheme was not welcomed by sailors, and several masters of vessels testified that it was unsuited to the purposes of navigation, and fitted rather to bewilder than to help the mariner, especially in circumstances when the lights are of the most importance.

Sir William Thomson returned to the subject of lighthouses in December last, and in a letter to *The Times* advocated his threefold reform which consisted in (1) a great quickening of nearly all revolving lights; (2) the application of a group of dot-dash eclipses to every fixed light; and (3) the abolition of color as a distinction of lighthouse lights, except by showing dangers, channels, and ports, by red, and white and green sectors.

"My proposal" he wrote "is to distinguish every fixed light by a rapid group of two or three dot-dash eclipses, the shorter, or dot, of about half a second duration, and the dash three times as long as the dot, with intervals of light of about half a second between the eclipses of the group, and of five or six seconds between the groups, so that in no case should the period be more than 10 or 12 seconds. This proposal has been carried into effect with perfect success in Holywood Bank Light, Belfast Lough, now the leading light for ships entering the Lough, but which until 1874 was enclosed in a red glass lantern, and was only visible five miles, and was constantly liable to be mistaken for a sailing vessel's port side light entering or leaving the harbor of Belfast, or the crowded anchorage of Whitehouse Roads. In 1874 the red glass was removed, and the light was marked by dot, dot, dash (— — ——, or letter U), repeated every ten or twelve seconds, and has been so ever since. It is now recognized with absolute certainty, practically, as soon as seen in ordinary weather from the mouth of the Lough, ten miles off, and has proved most serviceable as leading light for ships bound for Belfast or entering the Lough. It is much to be desired that the dot-dash system should be seriously considered by the lighthouse authorities of our islands. Hitherto, when attention has been called to it, it has been dismissed with pleasantry, "Winking lights won't do," or else something utterly different has been gravely considered and justly condemned. Is it too much to hope that when the new Eddystone Lighthouse is finished the light shall not be, as hitherto, an undistinguished fixed light, but a fixed light distinguished by a group of dot-dash eclipses—such as dot, dash, dot (— —— — letter R)—which is particularly easily distinguished by its rhythmical character; and that the Needles Light, which shows red over a great area of sea south of it, and when distinguished, as at present, is liable to be inconveniently and even dangerously mistaken for a ship's port side light, shall have a distinctive dash, dot (—— — or letter M) given to it, which, whether in its red or on its white sectors, will instantly show it to be itself and no other light at sea or on shore? The five years' practical demonstration of the dot-dash system in Belfast Lough ought surely to weigh with the authorities. The introduction of a well-proved remedy for an admitted defect of our lighthouse system should not need that advocacy which moved the unjust judge, and the sea-faring world should not suffer the delay in gaining a great benefit which the strict following of that judge's precedent would entail."

The Committee of Lloyd's, immediately after the letter was published, wrote to the Board of Trade, stating that they considered Sir William Thomson's idea that each lighthouse should furnish some distinctive mark by which it may be recognized, and not confounded with any other, was well worthy of consideration. The Board of Trade accordingly formally brought the subject under consideration of the authorities having charge of lighthouses in England, Scotland, and Ireland,

and in due time reports were returned to the Board.

Messrs. D. & T. Stevenson, the engineers to the Board of Northern Lighthouses, in their report, say that the essential principle of the simple lighthouse characteristics at present in use is that of optical distinction and strongly marked, and therefore obvious differences in the periods of light and darkness, while the proposed system consists of intricate and minutely different numerical distinctions in number and order of eclipses crowded into very short periods.

The origin of such schemes as that of Professor Babbage and Sir William Thomson is, according to Messrs. Stevenson, an erroneous idea regarding facts which are well established. There is a current and widely diffused, though wholly unfounded notion, that the great cause of shipwrecks is the mistaking of one light for another by the mariner. Mr. Alan Stevenson, in 1851, showed by statistics of the Scotch coasts for four years that the real cause of shipwrecks at night was not the mistaking of one light for another, but rather the nonvisibility of the lights. Out of 203 shipwrecks occurring in these four years, 133 occurred by night, and in only *two* of of these was it ever alleged that the appearance of the light had not been recognized, and in only one of these two cases were the lights specified that were alleged to have been mistaken for each other, viz., the *revolving* light of Inchkeith for the *fixed* light of the Isle of May. The grand requisite of all sea lights is penetrative power, and not a great variety of characteristics; and they should be distinguished either by purely *optical* characteristics, *i.e.*, by appearances at once appreciable by the eye, or else by broadly marked *variations* of periods, and not by minute differences exhibited in rapid succession indicative of certain letters of the alphabet, which could only be read by people trained to such a system of telegraphy, or the modification of this system now proposed by Sir William Thomson. Messrs. Stevenson, in conclusion, say that the system of altering all fixed lights to the dot-dash, or Morse alphabet system, would, from the minute differences in characteristics, lead not only to perplexity in the mind of the sailor, but we fear to disastrous results; and that such a mode of distinction, though it were free from danger, is uncalled for, because unnecessary.

The Elder Brethren of the Trinity House also declined to recommend the adoption of the Morse alphabet as being superior to the methods now in use, or better adapted to the comphrehension of every grade of martime intelligence. It is believed, they say, that if each light of the whole cordon round the coast were taken *seriatim*, there is not one whose identification could not be secured by observations far rougher and less minute than would be required for determining the existence and the sequence of longs and shorts.

The Commissioners of Irish Lights were found to be less inimical to the new system than other authorities. It would be injudicious, they believe, to adopt the dot and dash system generally, but the group flashing system could be applied with advantage to those lighthouses on the Irish coasts by which the transatlantic vessels shape their courses. It would be of incalculable use to the masters that on first making land, either in dark or foggy weather, they should have an unmistakably defined light. The Commissioners point out the concurrence of opinion between their scientific adviser, Dr. Tyndall, and Sir William Thomson. Dr. Tyndall said that it would be easy to give every lighthouse supplied by gas so marked a character that a sailor should recognize it with infallible certainty, and in carrying out his recommendations the Commissioners were very early impressed by the extraordinary facility with which, by the simple turning on and off of gas at any required interval, distinctive variations, to almost any extent, might be made in lighthouse lights, without impairing in the slightest degree the great penetrative power of the light itself. So far back as 1867 they applied this system to Wicklow Head, where, by a very simple piece of clockwork, the light is turned on and off, so as to cause a light of ten seconds, and an interval of darkness of three seconds duration; and in 1871 at Mine Head the same principle was adopted with fifty seconds light and ten dark. The use of gas in other lighthouses was recommended, and in 1877, with the approbation of the Board of Trade, the Commissioners placed at the

new lighthouse at Galley Head a group flashing gas-light, which was lighted in the following year, and is now, they believe, the most striking example in the world of this kind of light, the flashes of the powerful quadriform revolving light at that station being broken up into groups producing an effect of unrivaled individuality. This system of group-flashing is capable of almost endless variations.

When so many experts are opposed to Sir William Thomson's system, there is not much chance of the introduction of the dot and dash flashes into light-houses. But his other suggestions have been more successful. The advantage of colored lights at important points is no longer insisted on. Even Messrs. Stevenson acknowledge that the use of color is attended with disadvantage, not only to men who are color blind, but to all mariners in foggy weather, when the white lights acquire a reddish hue so as to simulate the effect produced by red shades.

ECONOMY IN ELECTRIC GENERATION.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

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THIS subject is one of no little importance at the present day of lightning speed. The scientific literature bearing on electricity has hard work to keep abreast with practical electricians. Instead of men now "thinking where others had but dreamed," they are acting where others had scarcely even dreamed. For instance, practical electricians have found that to generate a current economically is one thing, while to obtain a maximum current from a given source, is quite another. Many books on electricity treat of the latter, while very few if any make a special point of economy.

In what follows, batteries will be first considered, and subsequently mechanical generators.

In any electric circuit the energy is equal to the product of the electromotive force and current strength; or, it is equal to the square of the electromotive force divided by the resistance; or, it is equal to the product of the resistance and square of the current strength. According to the last, if there be no resistance for a given current there will be no energy. But if there exists a certain resistance to the current, the resistance and current being constant, a certain definite number of foot pounds of energy per minute will be required to maintain the current. It appears to be immaterial as to where or what that resistance is, whether internal or external; that is, whether it be in the generator, external to it, or divided between them. In practice, however, it will usually be divided between them. If the generator be a given lot of equal battery elements, it has been determined that the *maximum* current, with given external resistance is obtained, when the batteries are so arranged that the internal resistance equals the external. But considering the energy required, as proportional to the whole resistance, it appears that in this case half the total energy is consumed in overcoming the internal resistance. If we could in some way reduce this internal resistance, and at the same time retain the same useful result, that is, the same current strength and external resistance; then, of course, that useful result would be secured with greater economy, or with a less expenditure of foot lbs. of energy; or in other words again, the electric generating apparatus would have a higher efficiency. This efficiency is stated only with reference to the useful result of working expenses, and not with any consideration of the first cost of apparatus. The latter will generally be increased as the efficiency is raised in the manner above named. There will therefore be a limit where the interest on the increased investment in first cost will offset the saving in working expenses.

As an example, let us investigate the case of electric generation with a lot of voltaic batteries. The form of battery

is immaterial to this investigation, whether it be Daniell's, Grove's, Bunsen's or other; but it will be convenient to assume that all the cells employed have the same working conditions, that is, that the electromotive force and internal resistance of all of them be the same, and remain constant. If, however, these conditions be different, some arrangement would be possible in each case, but the present problem is a general one in efficiency instead of a special one in the arrangement of a lot of heterogeneous battery elements.

Let N = total number of equal cells: $= nm$;
n = number in each row, or in series;
m = number of rows, or number in multiple arc;
e = electromotive force of each single cell;
r = internal resistance of each single cell;
l = external resistance;
E = electromotive force of whole battery;
C = current strength of circuit;
R = total resistance of circuit;
z = zinc consumed.

To this case the well known law of Ohm applies, or

$$C = \frac{E}{R} = \frac{ne}{\frac{nr}{m} + l} = \frac{ne}{\frac{n^2 r}{N} + l} \quad . \quad . \quad . \quad . \quad (1)$$

The equivalence of these expressions is readily perceived, from the fact that the total electromotive force is equal to the sum of the individual ones, e, in a series, and the fact that the internal resistance is equal to the sum nr, of one series, divided by the number m, of series, the total resistance being therefore $\frac{nr}{m} + l$. Also we may eliminate m, by aid of the equation $N = mn$.

Perhaps no better way of securing the present object can be devised than to take the maximum current of a given lot N, of cells for the given current, and then find the conditions, if any exist, for securing the same current more economically. To find the maximum current realizable from N cells by varying n and m, take C = the least expression of (1) and place the differential of C with respect to n equal o. We thus obtain the well-known relation for the arrangement, giving the maximum current from a given number of cells, viz:

$$n = \sqrt{\frac{Nl}{r}} \quad . \quad . \quad . \quad . \quad (2)$$

This placed in the expression $\frac{n^2 r}{N} + l$, gives $2l$ for the total resistance of the current. This reiterates the well known fact that the maximum current is obtained from N cells when the arrangement in series and multiple arc is such that the internal resistance equals the external.

Applying the law of Joule, or its equivalent, to our battery circuit we have the

$$\text{current energy} = RC^2 = EC = \frac{E^2}{R} \quad . \quad (2')$$

where R is the total resistance. When the internal resistance is equal to the external, it appears that half the current energy is expended in overcoming useless internal resistance. The consumption of zinc being proportional to the energy of current, the amount of zinc required is here double what it would be if the internal resistance could be zero.

In seeking to economize zinc, we must in some way reduce the internal resistance. To do this, and at the same time maintain a constant current strength, it is plain that more than N cells will be required; because, for the number N, the given current is the maximum. But if economy of zinc follows from the addition of a few cells, it will be advisable to do so, and to what extent is determined, only, by comparing cost of battery cells as an investment with a saving in the running expenses. To ascertain the number of cells to add, let N, n, m and z, be changed to N', n', m' and z'; other things remaining constant.

Then

$$C = \frac{n'e}{\frac{n'r}{m'} + l} = \frac{ne}{2l} = \frac{n'e}{\frac{n'm}{m'n} l + l} \quad . \quad . \quad . \quad (3)$$

the last expression being equivalent to the others, from the fact that for the maximum current above, we have

$$\frac{nr}{m} = l.$$

This gives

$$\frac{m}{m'}=2-\frac{n}{n'}\ \&\ \frac{n}{n'}=2-\frac{m}{m'} \quad . \quad . \quad . \quad (4)$$

$$\frac{N}{N'}=\frac{mn}{m'n'}=\frac{m}{m'}\left(2-\frac{m}{m'}\right)=\frac{n}{n'}\left(2-\frac{n}{n'}\right) \quad . \quad (5)$$

$$\frac{m}{m'}=1\mp\sqrt{1-\frac{N}{N'}} \quad \frac{n}{n'}=1\pm\sqrt{1-\frac{N}{N'}} \quad . \quad (6)$$

$$\frac{z}{z'}=\frac{EC}{E'C}=\frac{neC}{n'eC}=\frac{n}{n'}=2-\frac{m}{m'} \quad . \quad . \quad . \quad (7)$$

The duplex signs in (6) indicate two arrangements, by which the equivalent current C may be realized when a certain number of cells have been added to that lot for which C is the maximum current. The arrangement obtained by using the upper sign in (6) economizes zinc, while the lower sign results in extravagance.

Equation (4) indicates that we may add until m' is infinite, in which case $n=2n'$. Also that by the other arrangement n' may be made infinite, for which $m=2m'$. The first is economical, and the last extravagant in zinc. These are the ultimate possible limits to which we can go by this method of procedure, that is, by finding the maximum current from a given number, N, of cells, and then adding to them for the purpose of securing the same current more economically. Of course we are not limited in this by the assumed current C, as evidenced by (1) and (3). Assuming C, we at once obtain, see eqs. (2), (3), &c.,

$$n=\frac{2Cl}{e} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

$$N=\frac{n^2r}{l} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

$$m=\frac{N}{n} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

for which C is the maximum current.

Example. In seeking help from a numerical example take

$$l=4.,\quad r=1.\quad N=144.$$

Then $$n=\sqrt{\frac{Nl}{r}}=24,\ \&\ m=6$$

for maximum current, which $=C=3e$.

Now suppose N be increased to $N'=192$, eq. (6) makes

$$\frac{m}{m'}=\tfrac{1}{2}\text{ or }\tfrac{3}{2}\ \&\ \frac{n}{n'}=\tfrac{3}{2}\text{ or }\tfrac{1}{2},$$

or $\quad m'=12$ or 4 : & $n'=16$ or 48 :

$$\&\ \frac{z}{z'}=\tfrac{3}{2}\text{ or }\tfrac{1}{2}\text{ : or } z'=\tfrac{2}{3}z\text{ or }2z$$

Hence in using the 144 cells in place of the 192, fifty per cent. more zinc will be required, for a given current worked a given time.

The relative quantities of zinc 1st for 144 cells, 2nd 192 economically, 3rd 192 extravagant, are as 3 : 2 : 6.

As another example take

$$m'=\infty,\ n=2n'\text{ and }z'=\frac{z}{2}$$

or $\quad n'=12$ and $C=3e$.

Again, if

$$n'=\infty\ \ m=2m'\text{ and }z'=\infty$$

or $\quad m'=3$.

The economical arrangement indicates that half the zinc is saved for the imaginary or impossible case where N′ and m' equal infinity, instead of 144; whereas if it be 192 instead of 144, the saving is a third, and is a result entirely practicable.

This extended comparison commenced soon after eq. (1), of the arrangement for a maximum of current with other cases, has been made partly to show that there is a real distinction between problems for maximum current and economy of zinc, and that the problem of the books for maximum current should not be confounded with the one not in the books for minimum of zinc.

But the maximum current arrangement is not necessarily taken into account in studying the economy problem. For instance, in eq. (1) if N and $m=\infty$

$$C=\frac{n'e}{l} \quad . \quad . \quad . \quad . \quad . \quad (10).$$

If C is made same as before, $=3e$, and $l=4$, then $n'=3l=12$, which is the same value as previously found for $m=\infty$. Again, if $N=192$, and $C=3e$, then eq. (1) $n=16$ or 48 same as before found for 192 cells.

Equation (10) determines the minimum number of cells in series for a given current strength C, external resistance l, and individual electromotive force e, for the case of either an infinite number of cells, or of a zero internal resistance. Also if the internal resistance $r=o$, only one row of cells is required.

To make a general solution of the case

of a battery working with a current C, against an external resistance l, and reasonable internal resistance, as compared with a battery of like cells arranged with zero internal resistance, and working with like external conditions, we have

$$C=\frac{n'e}{l}=\frac{ne}{\frac{nr}{m}+l}=\frac{ne}{\frac{n^2r}{N}+l} \quad . \quad . \quad . \quad . \quad (11)$$

$$\frac{n}{n'}=\frac{nr}{ml}+1=\frac{n^2r}{Nl}+1 \quad . \quad . \quad . \quad . \quad (12)$$

$$\frac{z}{z'}=\frac{neC}{n'eC}=\frac{n}{n'} \quad . \quad . \quad . \quad . \quad . \quad . \quad (13).$$

It appears from these that for zero internal resistance, the number of cells in series is proportional to the current C; also that in all cases, for a given current, &c., the consumption of zinc is simply proportional to the number of cells in series. This last corroborates eqs. (4) and (7), the first of which says that if $m'=\infty$ the current requires half as many cells in series as the same current when a maximum; while the second says, that when $m'=\infty$ the zinc consumption is reduced one half.

In Dynamo-electric and Magneto-electric machines will be found opportunity for applying the above principles and conclusions to some extent. The application which is most obvious, and at the same time most important, is that pertaining to the relative resistances, internal and external. From the fact that zinc consumed in batteries has a definite mechanical equivalent, or known value of foot lbs. of energy per lb. of zinc, it appears that the energy developed by a quantity of zinc in a battery may be treated quantitatively from its electrical effects, as well as the energy of a steam engine from its dynamo-electric effects. Though the exact relation in the latter is more complex than in the former, because of the varying nature of the internal resistance, yet that resistance, known or unknown, must stand in the same relation to the external resistance, as regards the foot lbs. of energy consumed for each, as has been above indicated for zinc consumed for each, in the case of batteries. Of course the foot lbs. here considered is that concerned in electrical effects, and exclusive of that consumed in overcoming resistance of mechanism. In magneto machines, where the magnetic field is maintained by permanent magnets, the internal resistance is less than in dynamo machines, because no portion of the circuit is included in coils of field electro magnets. This is favorable for the employment of permanent magnets.

In machines like the Wilde's, where the field magnets are excited by a supplementary, or exciting machine; the sum total of energy consumed, for a given external effect, is to be known in order to consideration of economy.

To this end let us suppose two machines put in comparison, giving the same current C, through the same external resistance L. In the first, or dynamo-electric machine, let the whole current have the circuit of armature and electro-field magnets whose resistances are R_1 and R respectively. Then the energy required to drive the machine, when in continuity of action, independent of the frictional resistances will be

$$\text{Driving energy}=C^2(R+R_1+L).$$

In the second let the exciting machine produce the same intensity of working magnetic field, with a field electro-magnet having the same volume of bobbin as in the first. This is perhaps fair because the first machine may have bobbins occupying all available room. Even then the second machine will be as large and expensive, independently of the exciting adjunct, as the first machine.

To maintain the same intensity of working field, we must have

$$I=NC=nc$$

where N is the number of turns of wire in first and n in the second of the main exciting bobbins; c being the exciting current in second, and produced by the exciting adjunct. The equation follows from the laws of electro-magnetic induction, making intensity of excited magnetism proportional to the number of turns of wire and to the current strength. Again, for equal volumes of bobbin the relation of the lengths will be that of the number of turns of wire, so that if S and s stand for sections of wire respectively, we have for equal volumes,

$$SN=sn$$

Again, the electrical resistance is pro-

portional to length and inversely as section giving

$$\frac{r}{R'}=\frac{S}{N'},\ \frac{n}{s}=\frac{n^2}{N^2}=\frac{C^2}{c^2}$$

r_1 being the resistance of the main exciting bobbin in second machine. The continued equalities follow from combining the two preceding equations with last.

Lastly, if r_1 be the internal resistance of the exciting adjunct, we have the total energy consumed in the second arrangement, or machine, the adjunct being considered part of it,

$$\text{Driving energy}=C^2(R+L)+c^2(r+r_1)$$

the last term standing for the energy consumed in the adjunct, and bobbins of main field magnets. But by combining c^2r with the next equation preceding it becomes C^2R_1, which, substituted, gives for the last named

$$\text{Driving energy}=C^2(R+R_1+L)+c^2r_1$$

the same as found for the first machine with exception of the excess of last term.

From this it appears that the second arrangement is more extravagant than the first. To diminish the last term, c or r_1 must be made less. As to the latter, we are brought to the same conclusion for the adjunct as for the principal machine, viz: economy requires the internal resistance to be a minimum. To decrease c, it will be necessary to use finer wire on main field magnet with more turns. The resistance of this bobbin will then be increased, which will hinder the prejudicial interactive currents, reducing the sum total of resistance, and possibly giving a resultant advantage. The consequent internal resistance, increasing with speed, often making the running internal resistance much greater than for the machine at rest, amounts to a serious drawback in consumption of power, heating of machine, &c. It is only in this, therefore, that we can expect to find advantage in employing what has above been termed, for convenience, the adjunct.

But if this gain is not found sufficient to cause the last term in the last equation above to disappear, then the first machine has advantage over the second. Finally, in those machines where, as is often the case, only part of the main current C is sent through the main field electro-magnets, we will evidently have the

$$\text{Driving energy}=C^2L+(C+c)^2R+c^2r$$
$$=C^2L+C^2R+2CcR+c^2R+C^2R_1$$

since $c^2r=C^2R_1$ by comparing with an equation above. Hence,

$$\text{Driving energy}=C^2(R+R_1+L)+2CcR+c^2R$$

the energy apparently being in excess by the last two terms. In this arrangement the gain over the first above, where whole current is sent through main field electro-magnets, is to be looked for in diminished internal consequent resistance, to an extent sufficient to cancel the last two terms above.

THE FUTURE OF THE IRON TRADE.

From "The Engineer."

When the demand for English rails sprang up some nine months ago in the United States, and the iron masters of Great Britain became exceeding glad, we suggested that the Iron and Steel Institute should send over a deputation of two or three of its members to ascertain by personal investigation carried out in the United States, whether the enormous demand anticipated was or was not to be regarded as legitimate; whether it was or was not likely that the railways proposed would really be constructed; whether the demand was to be looked on as altogether abnormal and temporary, or as the natural outcome of the growing wealth of the New World. Our advice was not followed but the demand for iron, in every shape and form, for the United States, attained proportions wholly unanticipated. It is not too much to say that some persons lost their heads and went mad for iron in any shape. Rails, pigs, bars, scrap, sheets, old rails, hoops, steel ingots, tires, came all alike. Nothing that could

be deemed iron or steel wanted a market. This was all very well up to a certain point; but unfortunately ironmasters believed that that which was but a passing wave was the rise of a tide, and they increased their powers of production enormously. In the United States precisely the same thing was done, and iron enough has been made in the last few months to satisfy the extra demands of the next year. The consequence is that iron returns to the price paid for it before the recent rage, and ironmasters find themselves with much money invested in new furnaces and plant for which they will never get a return. The events of the last nine months have been exceedingly instructive, however; and if only the lessons taught are taken to heart something will have been gained in return for an enormous outlay.

We learn, then, in the first place, that at no time in the future will it be possible permanently to raise the price of ordinary pig iron above 45s. per ton, or the price of steel rails above £6—probably we should be nearer the mark if we said £5. All calculations of profit and loss, wages, cost of coals, and so on, must be based on these figures, and estimates resting on prices higher than these will prove misleading. It may be a very unpleasant thing to be told that 40s. is likely to be a fair price for pig iron in the future, but the truth must be said, and should be accepted and acted upon. It is not difficult to see why the price must be kept somewhere about the figure we have named. The ironmaking plant of the civilized world is now much larger than it need be. No demand of at all a permanent character can exist which would tax all the blast furnaces of the world to supply it. To prove that this is true, we have only to possess ourselves of the fact that there is not now an iron-producing district of any importance in the world in which furnaces may not be seen which are out of blast. Not that they are out of order and therefore idle, but idle simply because there is no work for them to do. But the moment a demand springs up, all the previously idle plant is started; and the production of iron is enormously increased; and the market is glutted, and prices fall at once. It is absolutely necessary that at present a large proportion of the iron-making plant of the country should be idle. If it were at work, iron would of necessity be so cheap that it would not pay to make it. Furthermore, the tendency of every sudden wave of demand is to augment the quantity of permanent plant, and the larger the amount of plant standing idle the greater will be the tendency to sell iron cheap, because, if it be possible to make a blast furnace earn even 2 per cent. per annum clear profit on its first cost, by selling its pigs at 35s. a ton, the manufacturer will rather do so than let the furnace stand idle. Indeed, very many furnaces are now kept going which are not paying one halfpenny of interest on their cost, the whole of the pigs which they are producing being stocked on the chance that they may yet be sold at a fair profit. To illustrate the ease with which the iron-producing power of the world is augmented in reply to a sharp demand, we may say that in October, 1878, there were in the United States 708 furnaces, of which only 251 were in blast. At the end of the year this number had increased to 265; but at the end of 1879 there were 388 furnaces in blast, out of a total of 697 furnaces which were either in working order or admitting of being put in working order. The increase was thus 123 furnaces, and assuming that each would make a little over 400 tons a week—a very moderate estimate—the total augmentation would be 50,000 tons per week, or, taking forty-five working weeks in the year, 2,250,000 tons per annum. But there remain still 309 furnaces not at work. If we allow that 200 of them are so situated that they cannot be worked at a profit, and must be regarded as useless, we have still 109 furnaces left as a reserve ready to be blown in at short notice, and capable of making, say, 40,000 tons of iron a week, or 1,800,000 tons per annum. In 1879 the United States made 3,070,875 tons of pig iron, and it is beyond question that the rate of production increased continually during the year, as more and more plant was started. The result of all this production was that a demand, which extended over a couple of years, would have proved of the utmost service to iron-making districts, was all supplied, and much more than supplied, in a few

months, and the value of pig iron has fallen no less than £4 per ton in the United States. The facilities provided by steam for intercommunication are now so great that the moment a demand occurs for any article or commodity in one country several others can rush to supply it. Accordingly, although England is 3000 miles from America, the demand in the last named country stimulated the trade in Great Britain, and it may be safely estimated that in the last twelve months we have made 2,500,000 tons more pig iron than we did in the preceding year. Little or none of this extra quantity has been used in Great Britain, nor has it gone to the continent. America has absorbed the larger portion of it; and there can be no doubt that the United States have at the present moment a great deal more iron than they can possibly use, and facilities for producing at any time more iron they can want—always provided that the consumer does not insist on having supplied to him in any one year as much iron and steel as he can use in two years. Under the circumstances, we have no hesitation in saying that the prospects of the iron trade in Great Britain are so bad as to justify almost the worst that can be said of them—that is, if low prices mean bad trade. It has recently been urged that as there are firms in the North who are actually blowing more furnaces now, that the prospect for the future cannot be very bad. It is to be assumed, it is urged, that ironmakers know their own business, and that they would not increase their powers of production if they did not anticipate a good trade. Those who reason thus know but half the truth. They know that furnaces are blown in, but they do not know why. The truth is that the furnaces started are put in blast only to work off orders given long ago. Thus we could name a firm in the North which contracted some time ago to supply a very large quantity of a given kind of pig made in a special district. This firm are now making iron to stock, yet they have to start another furnace solely to comply with the terms of the contract; as the price is very good, not much harm is done. It will be found that in almost every case where plant is being increased peculiar conditions have dictated that increase.

As regards the future price of pig iron, it appears that that must be determined almost entirely by wages—not wages to the ironmaker alone, but wages to the collier and the ironstone miner. Plant exists in profusion. There is much more than enough of it, and if wages could be cut down sufficiently, then pig iron might be made at a profit for about £1 per ton. But it appears as though, both in this country and the United States, wages had been reduced almost as low as they can be got. There is nothing else to which the consumer can look just now for a chance of getting cheaper iron than a reduction in wages; and until this takes place iron will not fall much below its present value. After a time those now making iron to stock will find that they must stop, and furnace after furnace will be blown out both here and in the United States. But this step can very little affect the price of iron. Furnaces will not be blown out while they can be worked at any profit, and whatever is the number that may be kept in blast, it will be found not to be less than that required to keep pig as cheap as wages will let it be. All the signs of the times indicate a great contraction in the demand for iron from Great Britain, and the sooner the truth is realized the better. The following extract from the report of Mr. Swank, secretary to the American Iron and Steel Association, holds out little prospect of better times for us: "We may here remark that we regard the claim that 1,500,000 gross tons of rails will be required by the new and old railroads of the country in 1880, and that American works cannot meet this requirement, as unwarranted by past experience and existing probabilities. It is true that in 1872 we required about 1,366,830 gross tons—1,530,850 net tons—but since the close of that year we have laid over 2,000,000 gross tons of steel rails, the superior wearing qualities of which must be considered in estimating the probable quantity of rails to be required this year for renewals of existing tracks, while the mileage of new roads to be finished in 1880 is not likely to greatly exceed the average of the three years 1870, 1871, and 1872, which was 6466 miles. Hence it is not probable that we shall require as many rails in

1880 as in 1872, and those that are required can all be made by American works." It may be pointed out that as regards the rail trade, our only customers worth consideration, apart from the United States, were British India, Australia, Canada, and Brazil. In the first four months of this year we exported 67 per cent. more steel rails than we did in the corresponding period of 1879. Of our total rail exports, the United States took 32½ per cent. against 1 per cent. last year; British India took 26.9 per cent.; Australia, 10.7 per cent.; British North America, 6.3 per cent.; Brazil, 4.1 per cent. The British colonies and the United States together took 78½ per cent. of the total exports this year and 60½ last year. The quantity taken by the colonies altogether has been 90,555 tons this year, against 70,613 last.

ON THE ROTATION REQUIRED FOR THE STABILITY OF AN ELONGATED PROJECTILE.

From Proceedings, Royal Artillery Institution.

By A. G. GREENHILL, M. A., Professor of Mathematics to the Advanced Class of Artillery Officers.

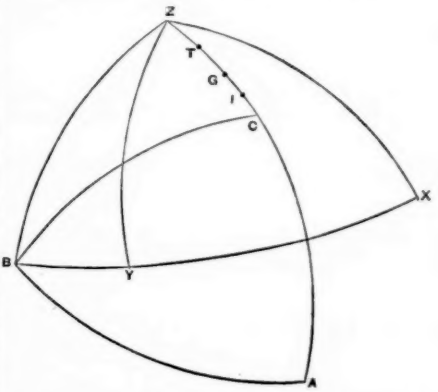
WHEN a body moves in a medium it sets the medium in motion, and the inertia of the body—that is its resistance to change of motion—is no longer necessarily the same in all directions, as it would be in a vacuum.

Consider an elongated projectile of revolution moving in air under no forces, and let c_1 denote the inertia of the body to motion perpendicular to its principal axis, c_3 the inertia of the body to motion in the direction of that axis; then if u, w be the component velocities perpendicular to and in the direction of the axis, $c_1 u$ and $c_3 w$ will be the components of linear momentum in those directions respectively; and if no forces act on the body, $c_1 u$ and $c_3 w$ will have a resultant, Z suppose, fixed in magnitude and direction, by the principle of the conservation of linear momentum.

If O be the center of the body, and if p be the component angular velocity about an axis OA, perpendicular to the axis of figure, then this motion of the body will stir up the surrounding medium; and if $c_4 p$ be the component angular momentum about OA of the body and medium, then c_4 is called the effective moment of inertia of the body about an equatorial axis.

If r be the component angular velocity about the axis OC of figure, then, since this angular velocity will not stir up the surrounding medium, the body being supposed to be a smooth solid of revolution, $c_6 r$ will be the component angular momentum about OC, c_6 being the moment of inertia of the body about OC; r will remain constant during the motion, the body being smooth and the medium frictionless.

Describe a sphere of unit radius with center O, and let OZ be the direction of the resultant linear momentum Z, OG of the resultant angular momentum G of the system, OC of the axis of figure. (In the figure the eye is supposed to be



at O, and looking at the concave side of the sphere—just as the eye sees the concave side of the celestial sphere.) The angular velocities p and r are estimated on the right-handed screw system (that is, an angular velocity r about OC is reckoned positive when on a right-handed

screw it would cause a transference from O to C).

If the center, O, of the body had been fixed, then OG, the axis of resultant angular momentum, would have been fixed, and the body would have behaved as if the equatorial and polar moments of inertia were c_4 and c_6; the axis OC would have described a right circular cone about OG as axis; and the motion might have been represented by rolling the right circular cone of axis OC and semi-vertical angle IOC, fixed in the body, on the right circular cone of axis OG and semi-vertical angle IOG, fixed in space; OI being the instantaneous axis of rotation, and therefore

$$\tan \text{IOC} = \frac{c_6}{c_4} \tan \text{GOC}.$$

But when the body moves steadily in the medium under no forces, O describes a uniform helix about a fixed straight line parallel to OZ, while OG, OI, and OC lie in a plane passing through OZ, which revolves with uniform angular velocity (μ suppose), while OC makes a constant angle (a suppose)with OZ, and OG makes a consant angle (θ suppose) with OC.

Then, if OA be the equatorial axis in the plane ZOC,

$c_1 u$ = component momentum in the direction OA = Z cos ZOA = $-$Z sin a,

$c_3 w$ = component momentum in the direction OC = Z cos ZOC = Z cos A;

and therefore, if OT be the direction of motion of O, the tangent to the helical path described by O,

$$\text{tan COT} = -\frac{u}{w} = \frac{c_3}{c_1} \tan a.$$

In consequence of the direction of motion OT not being in the direction of the axis OC, the body will experience a couple about the axis OB, perpendicular to the plane AOC, of magnitude.

$$(c_3 - c_1) uw = \frac{c_3}{c_1} (c_1 - c_3)\, w^2 \tan a.$$

Since the rate of change of angular momentum is equal to the impressed couple, therefore

$$G\mu \sin (a - \theta) = \frac{c_3}{c_1} (c_1 - c_3) w^2 \tan a. \quad \ldots \quad (1)$$

But

G cos θ = component angular momentum about OC = $c_6 r$,

$-$G sin θ = component angular momentum about OA = $c_4 p$;

and $p = -\mu \sin a$,

since the velocity of C, considered as due to the angular velocity about OA is p, and due to the angular velocity about OZ is $\mu \sin a$, and these are in opposite directions.

Therefore $G \sin \theta = c_4 \mu \sin a$,

and $$\tan \theta = \frac{c_4 \mu}{c_6 r} \sin a.$$

But, from (1),

$$G\mu \sin (a - \theta) = c_6 r \mu \frac{\sin (a - \theta)}{\cos \theta}$$

$$= c_6 r \mu (\sin a - \cos a \tan \theta)$$

$$= c_6 r \mu \sin a - c_4 \mu^2 \sin a \cos a$$

$$= \frac{c_3}{c_1} (c_1 - c_3) w^2 \tan a;$$

and dropping the factor sin a, which equaled to zero would imply perfect centering,

$$c_6 r \mu - c_4 \mu^2 \cos a = \frac{c_3}{c_1} (c_1 - c_3) \frac{w^2}{\cos a},$$

or $$c_4 \cos a \mu^2 - c_6 r \mu + \frac{c_3}{c_1} (c_1 - c_3) \frac{w^2}{\cos a} = 0; \quad \ldots \quad (2)$$

a quadratic equation in μ.

Solving this quadratic,

$$\mu = \frac{c_6 r \pm \sqrt{\left\{ c_6^2 r^2 - 4 \frac{c_3}{c_1} (c_1 - c_3) c_4 w^2 \right\}}}{2 c_4 \cos a},$$

and therefore the least admissible value of r, in order that the roots of this quadratic should not be imaginary, is given by

$$c_6^2 r^2 = 4 \frac{c_3}{c_1} (c_1 - c_3) c_4 w^2,$$

or $$\frac{r^2}{w^2} = 4 \frac{c_3}{c_1} (c_1 - c_3) \frac{c_4}{c_6^2}.$$

If the shot had been fired from a gun of caliber $2a$, the rifling at the muzzle making one turn in n calibers, and β being the angle of rifling at the muzzle, then

$$\tan\beta=\frac{\pi}{n}=\frac{ar}{v^2}=2a\sqrt{\frac{c_2}{c_1}(c_1-c_3)}\frac{c_4}{c_6}. \quad \ldots \quad (3)$$

If W = weight of shot,

W′ = weight of air displaced,

then
$$c_1=\mathrm{W}+\mathrm{W}'a,$$
$$c_2=\mathrm{W}+\mathrm{W}'\gamma,$$
$$c_4=\mathrm{W}k_1^2+\mathrm{W}'k'^2_1a',$$
$$c_6=\mathrm{W}k^2;$$

where k_1, k are the radii of gyration of the shot about OA and OC, and k'_1 of the air displaced (supposed rigid) about OA; a, γ, a' being certain quantities depending only upon the external shape of the body.

Where, as in practice, the fraction $\frac{\mathrm{W}'}{\mathrm{W}}$ is so small that its square may be neglected, we have

$$\tan^2\beta=\frac{\pi^2}{n^2}=4\frac{c_2}{c_1}(c_1-c_3)\frac{a^2c_4}{c_6^2}$$
$$=4\frac{\mathrm{W}+\mathrm{W}'\gamma}{\mathrm{W}+\mathrm{W}'a}\cdot \mathrm{W}'(a-\gamma)a^2\frac{\mathrm{W}k_1^2+\mathrm{W}'k'^2_1a'}{\mathrm{W}^2k^4}$$
$$=4\frac{1+\frac{\mathrm{W}'}{\mathrm{W}}\gamma}{1+\frac{\mathrm{W}'}{\mathrm{W}}a}\cdot \frac{\mathrm{W}'}{\mathrm{W}}(a-\gamma)a^2\frac{k_1^2+\frac{\mathrm{W}'}{\mathrm{W}}k'^2_1a'}{k^4}$$
$$=4\frac{\mathrm{W}'}{\mathrm{W}}(a-\gamma)\frac{a^2k_1^2}{k^4} \quad \ldots \quad (4)$$

+ higher powers of $\frac{\mathrm{W}'}{\mathrm{W}}$, which are neglected.

The only body for which a, γ, and a' have been, as yet, determined by mathematicians is the ellipsoid, the surrounding medium being supposed frictionless and incompressible; and for the particular case of the prolate spheroid of semi-axes a and c,

$$a=\frac{\mathrm{A}}{\mathrm{A}+\mathrm{C}},\quad \gamma=\frac{\mathrm{C}}{2\mathrm{A}},$$

and

$$a'=\frac{\mathrm{A}-\mathrm{C}}{\frac{c^2-a^2}{c^2+a^2}(2\mathrm{A}+\mathrm{C})-\mathrm{A}+\mathrm{C}}\left(\frac{c^2-a^2}{c^2+a^2}\right)^2;$$

where

$$\mathrm{A}=\int_0^\infty\frac{d\lambda}{(a^2+\lambda)^2(c^2+\lambda)^{\frac{1}{2}}}$$
$$=\frac{c}{a^2(c^2-a^2)}-\frac{1}{2(c^2-a^2)^{\frac{3}{2}}}\log\epsilon\frac{c+\sqrt{c^2-a^2}}{c-\sqrt{c^2-a^2}},$$

$$\mathrm{C}=\int_0^\infty\frac{d\lambda}{(a^2+\lambda)(c^2+\lambda)^{\frac{3}{2}}}$$
$$=\frac{1}{(c^2-a^2)^{\frac{3}{2}}}\log\epsilon\frac{c+\sqrt{c^2-a^2}}{c-\sqrt{c^2-a^2}}-\frac{2}{c(c^2-a^2)}. \quad (5)$$

and
$$2\mathrm{A}+c=\frac{2}{a^2c}.$$

From equations (4) and (5) Captain J. P. Cundill, R.A., has calculated a table of values of a—γ and the corresponding value of n for service projectiles, and the results obtained appear to agree very fairly with what is observed in practice. (See table, next page.)

It may be noticed from the formula that, on the hypothesis of the incompressibility of the medium, the value of n is independent of (1) the velocity, (2) the caliber, or length of bore; so that, for similar projectiles, one value of n would do for all guns in the service.

When, however, the velocity is high and the projectile is large, the compression of the air cannot be neglected, and the air behaves as if its density were increased; so that less rotation is required than that given by the formula.

For instance, the 80 and 100-ton guns are rifled at the muzzle with a twist of one turn in 50 calibers, while the formula would give one turn in 40 calibers as requisite for common shell three calibers long.

* "Quarterly Journal of Mathematics," Vol. XVI. "Mathematical Papers of the late George Green," edited by the Rev. N. M. Ferrers, p. 322.

TABLE CALCULATED BY CAPT. J. P. CUNDILL, R.A., FOR STABILITY OF ROTATION OF PROJECTILES.

Length of Projectile in cals.	Value of $a-\gamma$.	Minimum twist at muzzle of gun requisite to give stability of rotation=1 turn in n calibers.			
		Cast-iron common shell: Cavity=$\frac{3}{27}$ths vol. of shell. (s.g. of iron=7.207.)	Palliser shell: Cavity=$\frac{1}{8}$th vol. of shell (s.g.=8.000.)	Solid steel bullet. (s.g.=8.000.)	Solid lead and tin, similar comp'n to M.-H. bullets. (s. g.=10.9.)
		Value of n	Value of n.	Value of n.	Value of n.
2.0	.49418	63.87	71.08	72.21	84.29
2.1	.52032	59.84	66.59	67.66	78.98
2.2	.54431	56.31	62.67	63.67	74.32
2.3	.56643	53.19	59.19	60.14	70.20
2.4	.58679	50.41	56.10	57.00	66.53
2.5	.60561	47.91	53.32	54.17	63.24
2.6	.62315	45.65	50.81	51.62	60.26
2.7	.63938	43.61	48.53	49.30	57.55
2.8	.65454	41.74	46.45	47.19	55.09
2.9	.66868	40.02	44.54	45.25	52.72
3.0	.68192	38.45	42.79	43.47	50.74
3.1	.69434	36.99	41.16	41.82	48.82
3.2	.70598	35.64	39.66	40 30	47.04
3.3	.71693	34.39	38.27	38.84	45.38
3 4	.72724	33.22	36.97	37.56	43.84
3.5	.73697	32.13	35.75	36.33	42.40
3.6	.74615	31.11	34.62	35.17	41.05
3.7	.75483	30.15	33.55	34.09	39.79
3.8	.76303	29.25	32.55	33.07	38.61
3.9	.77082	28 40	31.61	32.11	37.48
4 0	.77820	27.60	30.72	31.21	36.43

THE FRENCH TRANS-SAHARAN RAILWAY.—Some time ago the French Ministry of Public Works received a grant of about £2400 to assist in making a survey of a railway route across the Sahara to Timbuctoo, whence it is proposed ultimately to continue the line to the French settlements in Senegal. Three expeditions have left Algiers on this service, each detailed to a different portion of the route. Colonel Flatters, who commanded the principal expedition, has recently returned to Marseilles. He reports having reached the 24th parallel, about half way between Algiers and Timbuctoo, and 90 miles or so south of the large oasis of El Golea. The expedition found a reasonable amount of water on the way, and from the nature of the formation it is probable that ample supplies might be obtained by deep boring all along the line. In one part of their journey the explorers discovered a lake, surrounded by vegetation, and full of fish. From the great numbers of antelopes and other game, these fertile spots are probably not infrequent in this part of the Sahara. The celebrated traveler, Soleilet, is on his way from Senegambia to Timbuctoo to trace the proposed railway in that direction. The French Senate on Tuesday last passed a vote of credit of nine million francs for a farther preliminary survey; and, even although neither line should ever be constructed, these expeditions are sure to benefit geographical science, if they do not also open out practical caravan routes to the interior.

THE DEPHOSPHORIZATION OF IRON.

ON THE DEPHOSPHORIZATION OF IRON IN THE BESSEMER CONVERTER.

By R. PINK, Hörde, Westphalia.

From "Engineering."

AT the opening of this communication I think it desirable to make some preliminary remarks, as I fear that otherwise the impression may prevail that, after a somewhat lengthened period of practice in dephosphorizing, even better results might have been obtained than those recorded here. The great object of this Institute is the promotion of progress in the industry whose name it bears. I trust you will allow that, if the progress here recorded has not been so rapid as some have expected, still, after making due allowance for the inevitable difficulties incident to grappling with a new system, a fair amount of success has been achieved.

It will be remembered that in April of last year, and again during the May meeting of this Institute, in presence of

many of its members, it was demonstrated that the problem of dephosphorizing iron in the Bessemer converter had, by the Thomas and Gilchrist system, been definitely solved at the works of Messrs. Bolckow, Vaughan & Co., under the direction of their talented manager. The Hörde Company, who had representatives at Middlesbrough and Eston during these experiments, at once determined also to test the process. It was then thought their plant was such as would make it comparatively easy for them to do this. They had a small plant of two 3-ton converters, and a larger one of three 8-ton vessels. There were at the time scarcely orders enough on hand to keep the larger plant going, and so the smaller one was left free for experimentation.

The revival of trade in the autumn of last year put quite a new phase on this condition of things. You are all aware that, in the heavy trades, when the harvest is ripe it must be gathered. This very revival of trade, welcome as it otherwise was and is, came at a conjuncture exceedingly unfavorable for the development of the new process, and in the midst of the experiments at Hörde attention had to be turned to the production of as large a quantity as both plants could possibly achieve. Owing to this circumstance, the new process had not the necessary time or space allotted to it for its sure and careful development, and, in reviewing what has been done, this fact must be taken into consideration.

The manufacture of good gray foundry pig at Hörde is always so costly that the margin of difference between it and Bessemer pig is too small to allow of this class of iron being used alone, and, considering the question entirely as one of dephosphorizing, it was determined to use poorer brands of white forge half-mine pig. In the use of this class of iron a claim may be laid to the progress before mentioned, and what has been done confirms both the possibility and probability of yet greater achievements in this direction. Without doubt we are making, from the very worst classes of pig iron, a most reliable and remarkably cheap steel.

In Hörde attention has not been paid to producing a better quality than that now in the market, but to making the same quality out of such irons as have just been mentioned. As good reliable rails are made by the Bessemer process with .08 per cent. of phosphorus in them, rails are made by the new process with .07 per cent. or .06 per cent., these being considered equal to all the requirements of railway material. For axles, tyres, plates, and wire billets the phosphorus is reduced to a much lower figure than this.

On the 22nd of last September, Hörde got, after great delay in looking for the best class of kiln to burn the bricks and dolomite in, one 3-ton converter at work, and at the same date rolled direct from the ingot the first rail manufactured under the Thomas patent in Germany. This rail stood exceedingly well under the tup, in spite of the phosphorus showing .12 per cent., but by the third charge the phosphorus was reduced to .06 per cent., and from this period, with but one exception, no difficulty has been found in keeping the phosphorus within the limits of .08 per cent. to .04 per cent.

At first, copying the example of Middlesbrough, iron was used containing as much as 1.5 per cent. of silicon, and it was determined to reduce this body by at least one-half. That it is possible to do so without detriment to the charge was soon apparent, as white forge pig containing but .73 per cent. of silicon was melted with 20 per cent. of steel scrap in the cupola without the metal boiling over in the converter in a sensibly higher degree than usual, while it allowed the ingots to be cast ascensionally. Guided by these results, silicon has always been kept low, and, as a consequence, white forge pig can be used instead of the much more costly foundry Nos. 1 and 2.

In order to increase the fluidity of this class of metal, and if possible to add an increment of heat, it was resolved to make a forge pig containing at least 1 per cent. of manganese, and, although the expectations entertained of thereby fluxing the basic additions at an earlier period in the charge have not been fully realized, this body doubtless does act as desired in the first two cases, and assists also to remove the sulphur that may be contained in the metallic bath. Man-

ganese may be termed the key to the use of cinder pig, where it can be cheaply and in sufficient quantities introduced into the iron in the blast furnace, or later in the Bessemer converter.

With the object of getting still greater heat on the metal, iron with larger percentages of phosphorus has been used, and the great value of this is clearly demonstrated; for when 2 per cent. of this metalloid is contained in the charge to be converted, groups of eight 10-inch ingots can be cast ascensionally with perfect ease, the steel being so quiet in the moulds as to allow of its being stoppered with light iron stoppers instead of the troublesome and dirty sand stopping.

Of course, the quantity of basic additions has to be increased, but not in so great a ratio as to be excessively expensive, or to cause trouble in the converter. Never less than 15 per cent. of good burned lime is used, be the amount of phosphorus what it may; and when working irons with upwards of 2 per cent. of phosphorus, 20 per cent. of lime is found quite sufficient. In the first case the lime is badly fluxed, and in the second the slag is very fluid. The fluxing of the lime has been attributed by many to the excessive waste of iron during the overblow, the oxides of which were supposed to reduce the slag to this state of fluidity, but on looking at the subjoined analyses it will be found that the waste of iron is not excessive.

To produce sound homogeneous ingots a good percentage of phosphorus—say between 1 and 2 per cent., or even in excess of this latter figure—appears to be indispensable, and irons containing so low a percentage as .5 do not appear suitable, unless this body is introduced in the charge by one or other of the known means, the best of which appears to be the use of ferro-phosphorus. That phosphorus can and does replace silicon, as a source of heat in the Bessemer converter, when working on the system Thomas-Gilchrist is no longer to be disputed.

The method of carrying out the process at Hörde is as follows: After heating up the converter, and without tipping out the coke used in so doing, the lime mixed with a little small coal is added, and, after blowing through for a few minutes, the metal is run in. In the three-ton converters the time occupied in blowing a charge of from 3 tons 10 cwt. to 4 tons, up to the vanishing point of the carbon lines of the spectrum, varies from 9 to 13 minutes, and the after-blow from 115 to 200 seconds. A test piece is taken shortly before the charge is considered as finished; this, when forged, is cooled in water and then broken, after which the blowing is continued as may be considered necessary. A second test piece is now rarely taken, as the first is so timed that a further half or three-quarter turn-up of the converter suffices to finish the charge. The slag is then run off and the spiegeleisen added. This running off of the slag prevents in a great measure the reduction of phosphorus out of the same, by means of the fluid addition.

Good sound burnt lime broken up to about the size of hens' eggs, and used as fresh as possible after burning, has been found to be the best basic addition; and could this be introduced cheaply and expeditiously in a white or red-hot state into the converters, it would prove of great advantage. The lining of the converters will be better protected during the oxidation of the silicon and a fluid slag earlier formed by this means.

The details of three charges are given below, and their analyses show clearly the chemical changes that take place during the blowing of the charge.

Charge No. 67, composed of

2400	lbs.	of foundry No. 3
3000	"	white forge
1000	"	steel scrap
420	"	spiegeleisen, containing 17 per cent. manganese.
6820	lbs.	total raw material.

Weight of steel produced, 6074 lbs.

Charge No. 68, composed of

2400	lbs.	of foundry No. 3
3000	"	white forge
1200	"	steel scrap
420	"	spiegeleisen, containing 17 per cent. manganese.
7020	lbs.	of raw material and 6250 of ingots.

Charge 69, composed of

1800	lbs.	of foundry No. 3
3600	"	white forge
1200	"	steel scrap
420	"	spiegeleisen, containing 17 per cent. manganese.
7020	lbs.	of raw material and 6302 lbs. of ingots.

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The total iron used in these three charges amounted to.....20,860 lbs.
And steel produced ....18,626 "

Giving a loss of .... 2235 "
or 10.17 per cent.

In the testing machine the following results were obtained:

Steel from charge No. 67 showed a tensile strength of 50.1 kilogs. per square millimeter of section (say 72,000 lbs. per square inch), with an extension of 20.6 per cent. and a contraction of area at point of breakage of 44.8 per cent.

Steel from charge No. 68 showed a tensile strength of 53.5 kilogs. per square millimeter of section, with an extension of 22 per cent., and contraction of area

ANALYSES OF CHARGE No. 67.

	P.	C.	S.	Mn.	Si.
Iron as taken from cupola.....	1.04	2.58	0.22	1.35	1.08
After blowing 11.75 minutes on fall of carbon lines.....	0.82	0.08	0.19	0.39	0.09
At overblow of 100 seconds.....	0 08	0.06	0.15	0.39	0.007
And further overblow of 15 seconds.....	0.045	0.04	0.14	0.37	0.005
After addition of spiegeleisen.....	0.06	0.28	0.067	0.46	0.002

ANALYSES OF CHARGE No. 68.

	P.	C.	S.	Mn.	Si.
Iron as taken from cupola..... ...	0.96	2.82	0.16	1.04	0.45
After 14 minutes blowing, and at fall of carbon lines.....	0.70	0.09	0.16	0.40	0.02
At overblow of 110 seconds.....	0.09	0.085	0.15	0.33	0.003
At further overblow of 15 seconds	0.05	0.08	0.09	0.29	0.000
After adding the spiegeleisen.....	0.06	0.26	0.055	0.31	0.000

ANALYSES OF CHARGE No. 69.

	P.	C.	S.	Mn.	Si.
Iron as taken from cupola.....	1.04	2.73	0.27	1.39	0.72
After 12 minutes blowing, and at fall of carbon lines.....	0.74	0.08	0.18	0.45	0.14
At 120 seconds afterblow.....	0.06	0.07	0.12	0.19	0.004
After addition of spiegeleisen.....	0.06	0.24	0.063	0 40	0.000

The slags contained 1.8 per cent. of metallic iron, and were composed as follows:

	Charge 67.	Charge 68.	Charge 69.
	per cent.	per cent.	per cent.
Silica.....	9.50	13.81	11.10
Phosphoric acid.....	9.76	7 38	12.43
Magnetic oxide ($Fe_3 O_4$).....	9.28	6.92	10.25
Peroxide of iron	..	1 41	
Oxide of manganese ($Mn_3 O_4$)	6.16	6.20	4.40
Lime.....	59.35	57.85	50.21
Magnesia.....	5.01	6.93	9.84
Sulphate of lime	0.87	0.22	1.15
Alumina.....	trace	trace	trace

at point of breakage of 47 per cent.

Steel from charge No. 69 gave a tensile strength of 54.3 kilogs. per square millimeter of section, with an extension of 19 per cent., and contraction of area at point of breakage of 42 per cent.

All the test pieces had a length of 150 mm., and a diameter of 15 mm.

These analyses and details must be apologized for to those members who are already acquainted with them. They are of an early date, but the Hörde Company do not feel justified in publishing later ones, pending the investigations of Geheimrath, Dr. Wedding, and Professor Finkener, as well as those of Dr. Müller and Dr. Fischer, the latter of whom has taken very elaborate samples of the gases evolved during the process and at the time of casting. These results will be public property at no very distant date, and will doubtless clear up certain hitherto conflicting theoretical views.

A repetition of the views propounded on the *rationale* of the process by the best metallurgists of the day would here be useless, as a large literature on this subject already exists, and the great interest excited is vouched for by the investigations not only of the gentlemen already mentioned, but of MM. Tünner, Grüner, Snelus, Pourcel, Jourdan, Riley, Ehrenwerth, Stead, Gautier, Massenez, &c.

The results of the three charges, Nos. 67, 68, and 69, show that without great loss of iron, silicon can be kept low, and by having manganese in the bath a great deal of the sulphur is also removed. These facts point to the wished-for end, namely, the use of a cheap cinder pig. The charges given only show a loss of 10.7 per cent., but the average loss at present comes up to about 17 per cent. When pit scrap, skulls, &c., are weighed in, this amount is reduced to something like 15 per cent.

A point of some importance in connection with this process is the blocking up of the converter with slag, and in cases where proper provision against this has not been or cannot be made, it proves the source of much delay. To provide against such a defect, many methods of fluxing the basic additions at an early period of the process have been tried with but negative success. At Hörde, however, a system has been used that is very promising; and when a proper isolating medium for separating the acid from the base is used, there is no doubt blocking up will be greatly reduced, if not entirely got rid of. The system referred to is the building in of good fire clay bricks on the points where the slag adheres, principally on the back of the throat and along the slag line of the converter when in its teeming position. At first, only 12 inches down the throat were so lined, but behind this the block-up was as great as usual. This zone was then deepened to 5 ft. in a converter of 16 ft., and the nose kept perfectly clean where the fire bricks were built in; still the slag blocked up directly below this zone. This is, however, of small importance, and, indeed, tends to keep the iron from boiling over, while its position in no way interferes with the regular working of the converter.

The blocking up of the converter appears not to be thoroughly understood; for whereas the Rhenish Steel Company have no cause of complaint with their 6-ton converters, and Hörde no difficulty with the 3-ton ones, the 8-ton vessel of the latter firm causes a good deal of trouble. No difficulty has been found in eliminating the phosphorus, even when such large patches of fire brick have been used as here are referred to.

The small converters can be much more rapidly manipulated than the larger ones, and the delay in taking the tests is not half so great. Delay is the cause of more blocking up than anything else. To avoid this, there appears as the very best remedy, exceedingly rapid manipulation of the whole plant and the reduction of the necessity of taking many, or any tests during the charge. When working with a perfectly known quantity of phosphorus and silicon, the former can be reduced to .07 or 0.08 without even once testing. Again, when the bottoms do not stand, the blocking up is very bad. This is no doubt caused by the insufficient fluxing of the dolomite loosed from the bottom. The slag, being then thicker, adheres more easily. In all cases, the heat of the charges has been greater and the blocking up less when using the highest obtainable blast pressure.

Great speed in working, together with

large ladles, that allow of rapid teeming, combined with a sufficiency of phosphorus and manganese, as also good bottoms, with a minimum duration of ten charges, and the use of fire brick zones at the points most liable to incrustation, appear to be the solution of this inconvenience. Bottoms cause trouble principally on account of the irregularity, giving at one time sixteen charges, and then, again, only four or five. The undoubted cause of this is the insufficient calcination of the dolomite, which, when exposed to the influence of the atmosphere after being ground, or even when grinding, rapidly absorbs moisture. It must be admitted that, if the causes of bad bottoms are as above stated, with more experience and care in preparing them they ought all to go up to the highest figure here given.

The average life of bottoms either rammed round pins or clay tuyeres reaches about nine charges, and with bricked ones better results have only been obtained occasionally.

Converter linings last, including the necessary patching, from 90 to 130 charges. Patching consumes about 50 per cent. of the amount of bricks required when first lining up, so that a 3-ton converter requires for, say, 120 charges, or a total production of 460 tons, as near as possible 4500 basic bricks.

The irons now used at Hörde are their own rejected foundry No. 3, foundry scrap, a half-mine forge pig, the white forge pig of Messrs. De Wendel, Messrs. Metz, of Luxemburg, and that of the Ilsede Company in the province of Hanover. This latter contains as much as 3 per cent. of phosphorus and about 2.5 per cent. of manganese.

The 3-ton plant produces about 40 tons daily, very nearly the same as when working the same converters acid lined. The shop is so cramped for room that rapid working is an impossibility.

In this department, tyres, axles, plates, and material for wire are solely manufactured. Upwards of 4000 tyres have already been turned out, and many hundreds of axles. Everything is cast ascensionally, the tyre ingots in groups of four, the axles in groups of three double ingots, whilst for wire, 8-inch parallel ingots in groups of four are cast. These latter weigh about 600 lbs., and are rolled down to 1¼-inch billets in one heat on a 12-inch train.

The 8-ton plant has, for want of sufficient basic material, and during the alterations now making, only one of the three converters working on the system. This has to take its turn with the others, and from causes mentioned at the commencement of this communication, the production has not been so regular as that of its small neighbor. Here only rail ingots are cast, in groups of eight, of 10-inch square. These are then rolled direct in one heat, without previous forging or cogging.

Doubts have been expressed as to the capability of producing hard steel by this process. Little experience has been gained in Hörde in this direction, as nearly all orders are for comparatively soft material. The axle orders are specified as not under 50 kilogs. of tensile strength per square millimeter of section, and a contraction at the point of breakage of not less than 35 per cent. For tyres, the lowest tensile limit is 45 kilogs., and the least allowable contraction 35 per cent. However, the sum of the tensile strength plus the contraction must reach 90.

Such conditions can be fully met, and many test pieces show up to 63 kilogs. with a contraction of 39 per cent. This being the general quality desired, no efforts have been made at producing harder steel.

In the softer qualities, for plates, wire, &c., it is at times astonishing what results are obtained. With 37 to 40 kilogs. of actual breaking weight, as much as 70 per cent., and in some cases even 75 per cent., of contraction has been reached. At the same time, this ingot iron can take very high heats, forging and rolling without a flaw. The production of this especial quality is so simple, the cheapness of the raw material, the certainty in working, its softness, and its ductility, all point to its driving at no very distant date puddled iron plates out of the market. For wire even of smallest gauges it has been declared better than that drawn from billets puddled from charcoal pig. Some small specimens are on the table for your inspection, and as most of the members will probably visit Düsseldorf during the autumn meeting, the exhibi-

tion there will show you what can be achieved in this respect.

An interesting and practical proof of the quality of this steel has been given during the last few days. The fire-tube of a Cornwall boiler, at one of the mines in the neighborhood of Dortmund, had to be removed on account of two of the plates bulging in. The water with which this boiler was fed contained such large quantities of common salt that an incrustation of several inches was formed in a very short space of time. Under these circumstances the plates got red-hot and buckled in. They show no flaw, although the indentations are in some cases 4 feet long, from 6 in. to 18 in. wide, and 7 in. or 8 in. deep. These plates were manufactured at Hörde under the system of Messrs. Thomas and Gilchrist in February of this year.

The character of plant that the Hörde Company possess is ill-suited to the requirements of this process, which accounts for its slow development, and Hörde has had the disadvantage of being the experimental bureau for Germany. In order to get the full benefit that the process undoubtedly brings, special plant should be designed for it. Spacious shops, with good facilities for clearing the pits of ingots and slag boxes, are very desirable; possibly also the converters should be built up in sections, and, above all, plenty of blast and great speed in working. When a charge of 8 tons of white forge iron, containing up to two per cent. of phosphorus, is converted, including the afterblow, in eight or nine minutes, the metal will be at least as hot as that when grey silicious pig is used by the old method. In proof of this, a charge of white phosphoric pig was blown in the presence of Geheimrath, Dr. Wedding, and Professor Finkener, and for the purpose of getting a correct diagram the charge was turned down no less than eight times to take the necesssary tests. The actual time of blowing was under nine minutes, and the steel ran ascensionally as well as could be wished for, without the least skull.

At the Rhenish Steel Works in Ruhrort, the process is worked even more successfully than at Hörde, and the following German firms have arranged for working, or are working, under this system; Messrs. De Wendel, Messrs. De Dietrich, Gienauth Brothers, Stumm Brothers, the Lothringen Iron Works at Ars on the Moselle, the Burbach Iron Works, the Rothe Erde by Aachen, the Bochum Company, the Königen Marien Works in Saxony, and others.

I have purposely avoided the theoretical side of the question, leaving this to be dealt with by those who have devoted so much valuable time to it, and who have already given, and in the immediate future will doubtless again give, you a library of information on the subject.

THE TAY BRIDGE.

From "The Architect."

THE reports of the Board of Inquiry into the "Circumstances attending the fall of a portion of the Tay Bridge on December 28, 1879," have been published, Colonel Yolland and Mr. Barlow being the joint authors of one, and Mr. Rothery of the second.

The report of Colonel Yolland and Mr. Barlow begins with a history of the Tay Bridge and a description of the mode of construction. In referring to the quality of the workmanship they say—

In regard to imperfection of workmanship and fitting, we observe, in the first place, that, as the substitution of iron in place of brick piers in this part of the work arose after the contract was let, there are no clauses in the specification describing the class of workmanship to be employed in them. The stipulation in the general specification, which requires all the holes in the flanges of the columns to be drilled, was not carried out in this part of the work as regards the holes in the flanges of the 18-inch columns. The holes in the lugs on the columns were all cast and left conical, instead of being drilled, thus allowing the pins to be bent and to have unequal bearings. Some of the sling plates which were made or altered at the works were roughly formed. Imperfection of

workmanship was also found in the bolt-holes of the struts, and as the struts did not abut against the columns, as in our opinion they ought to have done, their action in these cases depended on the friction or resistance to movement made by bolting the channel irons tightly together and bearing hard against the lugs. The columns after the accident were found in some instances to be of unequal thickness, and to have other defects of casting, and it was probably due to the sluggish character of the metal and the manner in which the columns were cast that the castings of the lugs did not always turn out sound, as out of fourteen tie bars attached to lugs tested in London, four showed unsoundness to a greater or less extent at the lugs. It is stated in evidence that, in some cases where lugs had turned out imperfect in casting, other lugs or portions of lugs were added by a process termed "burning on." This is admitted to have been done; but it is denied that any columns so treated were used in the permanent structure, and, although a large number of broken lugs are visible in the ruins of the fallen bridge, none were found during Mr. Law's examination, nor have been otherwise brought to our notice, which appear to have been subjected to this most objectionable and dangerous process.

The subject of wind pressure is afterwards considered, and the two Commissioners are of opinion that Sir Thomas Bouch, the engineer of the bridge, was not justified in supposing that Sir John Hawkshaw and other engineers had affirmed that no special provision for wind pressure was requisite:

We think he must have misunderstood the nature of that report, for as it is pointed out that the pressures in gusts of wind amounted to 40 lbs. or 50 lbs., it was obviously necessary to provide for the pressures of these gusts in each of the spans of the Tay Bridge; and although the limited area of these gusts is described as not being at all comparable to that of the Forth Bridge of 1,600 feet span, yet they might in effect be equal to the whole area in the Tay bridge spans of 245 feet, and their operation might take place upon any of the spans. It must not be understood, however, that we express an opinion as to the sufficiency of a provision for only 10 lbs. of wind pressure in a large span of 1,600 feet. It may represent an amount of force which, as applied to the whole surface, would rarely be exceeded, but it occurs to us as possible that two or more gusts might act simultaneously on so large a span, or there might be a wind gust of unusual width. . . . In the great majority of railway structures, namely, those made in brickwork and masonry, as well as iron bridges of moderate height and span, special provision is not required for wind pressure, because the weight and lateral strength imparted to such structures in providing for the strains due to dead weight and load is more than sufficient to meet any lateral wind pressures which can arise. Also, in girders up to considerable spans, the lateral stiffness given to them to resist the tendency to oscillation produced by moving loads at high speeds is generally sufficient to meet the requirements of wind pressures; and the evidence of Sir Thomas Bouch implies that, having provided amply for dead weight and moving loads in the Tay Bridge, he did not consider it necessary to make special provision against wind pressure.

The gradual deterioration of the bridge, and the causes to which Colonel Yolland and Mr. Barlow attribute the accident, are thus described:

The first indication of weakness in the bridge itself was the loosening of a number of the ties of the cross bracing, a fact observed by the inspector, Henry Noble, in October 1878. He did not communicate this fact to Sir T. Bouch, but procured iron and packed the gibs and cotters, using for this purpose more than 100 iron packings about three-eighths of an inch thick in different parts of the bridge. All the evidence relative to the condition of the ties states that they were, to all appearance, in proper order at the date of the inspection by General Hutchinson, on February 25, 26, and 27, 1878. The loosening which subsequently ensued must have resulted from lateral action, and was most probably due, as Sir T. Bouch suggested, to strains on the cross-bracing produced by storms of wind. Sir Thomas Bouch considers that the effect produced arose from the bending of the pins in the holes, which had been left

conical in casting the lugs, and it was, we think, one of the causes; but the small bearing surfaces between the gibs and cotters and the tie bars, only about .375 of a square inch, would tend to increase this effect, and it might have been further increased by displacement or movement at the ends of those struts where the fitting was imperfect.

In October or November, 1879, three of the columns were ascertained by Mr. Noble to be cracked with vertical cracks, two of them being in the Northern part of the bridge still standing, and one in pier No. 38 under the high girders. The inspector (Noble) bound these columns round with wrought iron bands, and communicated this fact to Sir Thomas Bouch, who came to the work, and, in reference to other defects pointed out by the inspector, decided to have extra bracings made for the curved part of the bridge north of the large girders. It has been already mentioned that the columns of the whole bridge were filled after their erection with Portland cement concrete, put in from the top, and concrete of this material, unless carefully managed, is liable to swell in setting. From this circumstance, and from the unequal contraction of cast iron and concrete by cold, internal strains might have arisen sufficient to produce such cracks. Cracks of a like character have occurred in other viaducts, and when the fracture is vertical it is capable of remedy to a considerable extent by hooping with wrought iron bands. In this state of the columns and ties, the storm of December 28, 1879, occurred, which would necessarily produce great tension on the ties, varying as the heavy gusts bore upon different parts of the bridge; and when under these strains, the train came on to the viaduct, bringing a larger surface of wind pressure to bear as well as increased weight on the piers, and accompanied by the jarring action due to its motion along the rails, the final catastrophe occurred.

The distance at which the girders were found from the piers, and the position of the wreckage on the piers, is such as would result from a fracture and separation occurring somewhere in the piers above the base of the columns, and such a fracture might have arisen from two causes—firstly, by the yielding of the cross-bracing, and the consequent distortion of the form of the piers, which would throw unequal strains on the flanges and connecting bolts; or, secondly, fracture might have occurred in one of the outer leeward columns, from causes similar to those which produced the fractures found in other columns shortly before the accident.

Sir T. Bouch states it to be his opinion that the accident was occasioned by the overturning of the second-class carriage and the van behind it by the force of the wind, that they were canted over against the girder, and that the force of the blow given by these vehicles at the speed at which they were traveling was sufficient to destroy portions of the girders, and so occasioned the fall. But in this opinion we do not concur, and do not consider that it is supported by the evidence of the engineers who were called on the part of the railway company, Sir T. Bouch, and the contractors. Dr. Pole, Mr. Stewart, and Mr. Baker, all of whom were called on behalf of Sir T. Bouch, although they suggest the possibility of some shock acting in addition to the wind pressure, all concur in attributing the first failure to the lugs of the cross bracing. Mr. Cochrane believes that if the columns had been strongly braced, strongly fitted, and strongly held down by holding-down bolts, the pier would have been standing now, and adds, "It is a question of cross-bracing, of course." In our opinion the weight of evidence points out the cross-bracing and its fastening by lugs as the first part to yield.

Such being the nature of the case brought under our consideration in this inquiry, we have to state as our opinion:

1. That there is nothing to indicate any movement or settlement as having occurred in the foundations of the piers which fell.

2. That the wrought iron employed was of fair strength, though not of high quality as regards toughness.

3. That the cast iron was also fairly good in strength, but sluggish when melted, and presented difficulty in obtaining sound castings.

4. That the girders which have fallen were of sufficient strength, and had been carefully studied in proportioning the several parts to the duty they had to

perform. In these girders some imperfections of workmanship were found, but they were not of a character which contributed to the accident, and the fractures found in these girders were, we think, all caused by the fall from the tops of the piers.

5. That the iron piers used in place of the brick piers, originally contemplated, were strong enough for supporting the vertical weight, but were not of a sufficiently substantial character to sustain, at so great a height, girders of such magnitude as those which fell. That the cross bracing and its fastenings were too weak to resist the lateral action of heavy gales of wind.

6. That, although a large staff of assistants and inspectors was employed, we consider that a sufficiently strict supervision was not exercised during the construction of that part of the work made at the Wormit Foundry. We think that the great inequality of thickness in some of the columns, the conical holes cast in the lugs, and several imperfections of workmanship which have been ascertained by this inquiry, ought to have been prevented.

7. That the arrangements for the supervision of the bridge after its completion were not satisfactory, inasmuch as it was intrusted solely to Henry Noble, who, though an intelligent man, and very competent in the class of work to which he had been accustomed, possessed no experience in structures of iron work, nor does it appear that he received any definite instruction to report as to the state of the iron work of the bridge.

8. That Henry Noble, having become aware that many of the ties of the cross-bracing were loosened in October, 1878, ought at once to have informed Sir T. Bouch of this circumstance. Had he done so, there would have been ample time to have put in stronger ties and fastenings before the occurrence of the storm which overthrew the bridge.

9. That the ties of the cross-bracing had been tightened up and brought to their bearing before the date of the inspection by General Hutchinson, and the fact that many of them became loose so soon afterwards, was an evidence of weakness in this part of the structure, and of a departure from the vertical of the columns where it occurred; and we think that the loosening of the ties to an extent sufficient to permit the insertion of pieces of iron three-eighths of an inch thick indicated a considerable change of form of the pier, and rendered it doubtful if the piers could have recovered their form when the wind action ceased. The employment of packing pieces, under such circumstances, might have had the effect of fixing the parts of the structure where they were applied in their distorted form.

10. That, notwithstanding the recommendation of General Hutchinson, that the speed of the trains on the bridge should be restricted to 25 miles per hour, the railway company did not enforce that recommendation, and much higher speeds were frequently run on portions of the bridge.

11. That the fall of the bridge was occasioned by the insufficiency of the cross-bracings and its fastenings to sustain the force of the gale on the night of December 28, 1879, and that the bridge had been previously strained by other gales.

12. That, although the general bearing of the evidence indicates the cross-bracing as being the first part to yield, yet it is possible that the fall of the bridge may have been occasioned by a fracture or partial fracture in one of the outward leeward columns, produced by causes analogous to those which fractured other columns shortly before the accident; for if a fracture or partial fracture of a dangerous character occurred in one of these columns, the extra strain brought on by the force of the gale, accompanied by the weight and tremor of the train, might have led to its final rupture.

13. That the first or southern set of continuous girders, covering five spans, was the first that fell after the engine and part of the train had passed over the fourth pier, and that the two consecutive sets of continuous girders, each covering four spans, were in succession pulled off the piers on which their northern ends rested, by the action of the first set of continuous girders falling over, and probably breaking some of the supporting columns.

14. That the extent of the work which fell was attributable to the employment

of long continuous girders supported by piers built up of a series of cast-iron columns of the dimensions used.

In conclusion, we have to state that there is no requirement issued by the Board of Trade respecting wind pressure, and there does not appear to be any understood rule in the engineering profession regarding wind pressure in railway structures; and we therefore recommend that the Board of Trade should take such steps as may be necessary for the establishment of rules for that purpose.

We also recommend, before any steps are taken for the reconstruction of the Tay Bridge, that a careful examination should be made of those parts of the structure left standing, especially as regards the piers, with a view to insuring such alterations and amendments as may be necessary to give to these portions of the work complete stability.

Mr. Rothery says that he agrees with his colleagues in thinking that there is no evidence to show that there has been any movement or settlement in the foundations of the piers; that the wrought iron was of fair quality; that the cast iron was also fairly good, though sluggish in melting; that the girders were fairly proportioned to the work they had to do; that the iron columns, though insufficient to support the vertical weight of the girders and trains, were, owing to the weakness of the cross-bracing and its fastening, unfit to resist the lateral pressure of the wind; that the imperfections in the work turned out at the Wormit Foundry were due in great part to a want of proper supervision; that the supervision of the bridge after its completion was unsatisfactory; that if by the loosening of the bars the columns got out of shape, the introduction of packing pieces between the gibs and cotters would not bring them back to their position; that trains were frequently run through the high girders at much higher speed than at the rate of 25 miles an hour; that the fall of the bridge was probably due to the giving way of the cross-bracing and its fastening; the imperfection in the columns might also have contributed to the same result. But he differs from them in the interpretation of the instructions under which the Court of Inquiry was held.

I apprehend (says Mr. Rothery) that if we think the blame attaches to any one for this casualty, it is our duty to say so, and to say to whom it applies. I do not understand my colleagues to differ from me in thinking that the blame for this casualty rests with Sir Thomas Bouch, but they consider that it is not for us to say so. Lastly, my colleagues, in their report, call attention to the fact "that there is no requirement issued by the Board of Trade respecting wind pressure, and that there does not appear to be any understood rule in the engineering profession regarding wind pressure on railway structures," and they therefore "recommend that the Board of Trade should take such steps as may be necessary for the establishment of rules for that purpose." I cannot, however, join in that recommendation, for it appears to me that if there is no understood rule in the engineering profession, regarding wind pressure on railway structures, it is for the engineering profession, and not for the Board of Trade, to make them. I will add, that if I rightly understood my colleagues at our last interview, they concurred in the conclusions to which I had come, that there might be a maximum wind pressure of from 40 lbs. to 50 lbs. per square foot, and this too, not only over a few feet, but over the whole extent of a span of one of the high girders, and I gather as much from their report. And, if so seeing that it is the practice in France to allow 55 lbs. per square foot for wind pressure, and in the United States 50 lbs., there seems to be no reason why a similar allowance should not be made in this country.

After an examination of the defects in the design as well as in the construction of the bridge, Mr. Rothery reports:

The conclusion, then, to which I have come is, that this bridge was badly designed, badly constructed, and badly maintained, and that its downfall was due to inherent defects in the structure, which must sooner or later have brought it down. For these defects in the design, the construction, and the maintenance, Sir Thomas Bouch is, in my opinion, mainly to blame. For the faults of design he is entirely responsible. For those of construction he is principally to blame in not having exer-

cised that supervision over the work which would have enabled him to detect and apply a remedy to them. And for the faults of maintenance he is also principally, if not entirely, to blame in having neglected to maintain such an inspection over the structure as its character imperatively demanded. It is said that Sir Thomas Bouch must be judged by the state of our knowledge of wind pressures when he designed and built the bridge. Be it so; yet he knew or might have known that at that time the engineers in France made an allowance of 55 lbs. per square foot for wind press ure, and in the United States an allowance of 50 lbs. And although there seems to have been no agreement among English engineers as to the allowance proper to be made, Mr. Brunlees told us that he allowed 30 lbs., and even Mr. Baker allowed 28 lbs. Sir Thomas Bouch was building a bridge on somewhat new principles, and in a position where it would be peculiarly exposed to the action of westerly and south-westerly gales; and not only does he make no allowance for wind pressure, but actually builds the bridge weaker and lighter and with wider spans than in his previous works. To have built and designed a bridge which, if properly constructed in all respects, would only have borne a lateral pressure of from 60 lbs. to 70 lbs. per square foot when a pressure of 40 lbs. or 50 lbs. of wind was quite possible, was a grave error of judgment. Whether, too, the calculation of its stability, or the maximum pressure of the wind be or be not erroneous, matters very little; the bridge fell in a gale of wind which, though violent, was not one which could not and ought not to have been provided against. It fell solely by the action of the wind, either when the margin of safety was too low or the defects too great. In neither way can Sir Thomas Bouch escape his responsibility.

I think, also, that Messrs. Hopkins, Gilkes & Co. are not free from blame for having allowed such grave irregularities to go on at the Wormit Foundry. Had competent persons been appointed to superintend the work there, instead of its being left almost wholly in the hands of the foreman moulder, there can be little doubt that the columns would not have been sent out to the bridge with the serious defects which have been pointed out. They would also have taken care to see that the bolt-holes in the lugs and flanges of the 18-inch columns were cast truly cylindrical, or, if that could not be done, they would have called the attention of the engineer or his assistants to the fact; but that does not appear to have been done. The great object seems to have been to get through the work with as little delay as possible, without seeing whether it was properly and carefully executed or not.

COMPRESSED AIR LOCOMOTIVES.

From "The Engineer."

THE bringing out of a limited company, with a large nominal capital, to work a locomotive engine driven by compressed air, is sure to arouse public attention to the merits and demerits of this form of motor. It cannot be denied that hitherto the demerits have been rather the more prominent of the two. As far as practical results go, great efforts were made to achieve the success of the Mekarski air engine at Paris, but the attempt, we believe, has been entirely abandoned. In Glasgow, Mr. Scott Moncrieff has built what appeared to be a promising engine of the same type but it lingers, we fear, in the inglorious inactivity of the shed. Even for those purposes, such as tunneling, in which compressed air has come largely into practical use, engineers agree that its efficiency is lamentably low, and that it is only its extreme convenience in other ways which makes its employment a necessity. It may be interesting, therefore, to our readers, to put before them the precise conditions of the problem which Col. Beaumont has attacked, and in the light of such facts as have been

placed before the public, to consider how far he may be credited with having solved it.

The great advantages that would follow from some cheap and convenient method of storing up power, to be given out at any subsequent time as needed, are so obvious that they do not need to be dwelt upon. At first sight it would seem that the compression of air was specially fitted to form a method of this kind. Air is readily and simply compressed to any required extent; it has practically no weight and no dangerous properties of any kind; a very large quantity of power can thus be stored up in a vessel of comparatively small size and weight, and when this power is required for use, the emission of the air is not only attended with no inconveniences, but in some circumstances, *e. g.*, underground, is absolutely beneficial. When, however, it is attempted to carry this promising device into practice, it is found that two great obstacles bar the way; firstly, the difficulty in preventing leakage; and, secondly, the great loss of useful effect which takes place both during the compression and during the expansion. The first difficulty, that of leakage, is entirely practical, and one that no engineer will undervalue; but it is obvious that it must be entirely overcome if the storing up of power is to continue for any considerable length of time. The second difficulty, the loss of useful effect, is of a more theoretical and recondite character, and by many engineers it is either ignored altogether, or regarded as something abstruse and mysterious. We believe, however, it can be made perfectly plain to anybody acquainted with the first principles of mechanical science, and we will therefore devote a few words to the subject.

With air, as with any other permanent gas, there are three properties, which may be said to exhaust all that, from a physical point of view, we can want to know about it, namely, its pressure, its volume, and its temperature. When, for instance, we know that a certain quantity of air occupies a reservoir whose content is 300 cubic feet, that a pressure gauge attached to that reservoir stands at 1000 lbs. to the square inch, and that a thermometer also attached registers 60 deg. Fah.—these are somewhere about the normal conditions of Col. Beaumont's engine, now running experimentally at Woolwich—then there is only one other question which we can need to ask concerning it; and that question is, "How great is your certain quantity?" This is answered by stating the volume of the same air under standard circumstances, *i. e.*, under ordinary atmospheric pressure and temperature. Thus to investigate any problem concerning air we must know four quantities—the pressure, the temperature, the volume, and the initial volume, or the volume under standard conditions. But, on examining the matter further, theory shows that these four quantities are so dependent on each other, that if any three be given the fourth can always be calculated from them; hence, if we take any given initial volume of air and follow it through changes of any kind, we find that its pressure always depends on its temperature and its volume, its volume on its temperature and its pressure, and lastly, its temperature on its pressure and its volume; so that any change that takes place in any one of these quantities will be followed immediately by a change, greater or smaller, in one at least of the two. To put the matter in another form, a given quantity of gas, whenever it has one particular volume and pressure, must always have one particular temperature, and *vice versa*. Now, to apply this to the case of compressed air. To fix our ideas, let the air be contained in a cylinder, of area equal to one square foot, and ten feet long; let there be a tight-fitting piston at one end of this cylinder, and let the air be compressed by forcing this piston towards the other end, and give out its store of power by driving the piston back again. Suppose the piston to be pushed forward 5 feet, then the particles of air, which occupied the whole length of 10 feet, must re-arrange themselves so as to occupy 5 feet only. Now, it is found that if the piston be moved with extreme slowness, the particles will do this quite easily and quietly, and that the thermometer at the end of the operation will stand exactly the same as it was at the beginning; in other words, the temperature will be unchanged. Hence, the work which has been done in pushing forward the piston against the resistance of the air is all

stored up in the form of "potential energy," and none of it in the form of sensible heat. The whole of this work will therefore be available at any future time for pushing the piston back again against any resistance that may oppose its doing so. Meanwhile, the pressure gauge, at the end of the operation, will be found to indicate just double the pressure it did at the commencement. The air has thus obeyed Boyle's law, according to which the pressure increases in exact proportion to the decrease of volume,

Now, let us make the opposite assumption, namely, that the piston is moved forward with extreme quickness. Then the particles have no time to take up the new arrangement quietly, as they did in the former case. They are driven forcibly together, and thrown into violent agitation; in other woods they are heated. The thermometer will stand, at the end of the motion, considerably higher than it did at the beginning. But this is not all. The pressure will be altered, not only in virtue of the change in volume, but also in virtue of the change in temperature. Practically the pressure gauge will stand much higher at the end of the motion than it did in the former case. And if the motion be now continued, it must be continued against this increased pressure; and much more work must therefore be expended in driving the piston, say through another foot, than would be needed if the first advance had been made slowly, as in the former case. This increase of pressure, due to increase of temperature, follows at once from the kinetic theory of gases, according to which pressure is simply the average effect of the continual impacts of the vibrating particles of the gas as they strike against the surface which contains them. It is obvious that the more intense the vibration the more violent the impacts, and therefore the higher will be the pressure that represents their effects. We may illustrate the case to ourselves, very roughly, in thinking of the difference there would be in compressing one swarm of bees which were inert, and another which were all alive and buzzing. In any case the fact is certain that the rise in temperature produces a rise in pressure, and a rise which is much higher in proportion; and the work to be done in any further compression will be increased accordingly. The result will be that, supposing in both cases the piston is pushed to the same distance, say 1 foot from the further end, the amount of work stored up as power in the compressed air will be much greater in the second case of rapid or "adiabatic" compression, than in the first case of slow or "isothermal" compression. And this second case comprises nearly all practical cases, since the time allowed for compression is always very limited.

Now, granting this result, it may be asked, "What does this matter? If there is more power stored up, there is more power to be got out, and that is all." But unfortunately that is not all. It would not be all even if the power were to be drawn upon immediately. But in point of fact the only object of the process is to form a permanent reservoir of power, on which we may draw, either at a great distance from the place at which it was formed, or at a long interval after its formation. Now, in the second of our two cases, which is that of practice, the compressed air is at a high temperature, much higher than that of the atmosphere; and before its power is utilized, it must needs be that much of this heat will have been dissipated. But this loss of sensible heat means a great reduction of pressure, just as the rise in sensible heat means a great increase of pressure: and hence the power which can be got out of the air, when the time of spending comes, is much less than there was contained in it at first. But this is not all. As practically the air must be compressed rapidly, so practically it must be expanded rapidly; the one process is the converse of the other, and the converse effects follow. Hence, as the first compression raised the temperature, and so produced an increase of pressure much beyond what was due to the decrease in volume, so also the first expansion will lower the temperature, and will so produce a decrease of pressure much beyond what is due to the increase of volume. And, as the energy put into the air, in practice, is much greater than would be put in if the compression was very slow or isothermal, so the energy that can be got out of it in practice is very much less than could be

got out of it if the expansion was very slow or isothermal.

The above explanation may perhaps serve to put in a clear light the two great defects which, under practical conditions, reduce the efficiency of compressed air to a very low fraction. Possibly it may also suggest to some minds what is the tolerably obvious remedy. Since both sources of loss are due to the fact that the air does not maintain itself at the same temperature throughout the two processes, is it not possible to maintain it at that temperature by artificial means? And this is, in fact, the method which has actually been followed. The idea and its application appear to be due to the mining engineers of France and Belgium. The method usually employed has been to inject cold water in the form of fine spray into the compressing cylinder, and hot water in the same form into the expanding cylinder. Of course such a remedy is only partial. The cold water prevents the air from taking up an increased temperature, but only by becoming heated itself; and this heat cannot to any great extent be utilized. Similarly the hot water must be heated artificially, and this heat cannot itself be rendered efficient; it merely acts to dimmish the loss of efficiency in the expanding air. Theory and practice, however, seem to show that this waste is not large, and moreover that it does not increase in proportion to the degree to which the compression is carried, but, on the contrary, is the same for the same amount of energy expended. Hence follows the important principle that the pressure at which compressed air should be employed should be as high as possible, since this enables the reservoir and other apparatus to be on a smaller scale, lighter, and more compact.

So far for the theory of the subject. We may next inquire how far its difficulties have been met in Colonel Beaumont's recent solution of the problem. Such as they are, they have been frankly recognized, and to some extent at least may be said to have been overcome. Colonel Beaumont has followed the French engineers in their endeavors to cool the compressed, and heat the expanding air; but instead of the spray method adopted by them, he has preferred to surround the compressing cylinders with cold water, and the expanding cylinders with steam at about atmospheric pressure. The former method has already been adopted by the Woolwich authorities, in the apparatus designed for producing the very high pressures of air required for torpedo work; and at present it is this very apparatus which is being used by Colonel Beaumont to charge his experimental engine. Probably this may have led him to adopt the parallel method of steam jacketing for the case of expansion. It is obvious that both arrangements are less complicated than the spray injection system, and, for very high pressure, have the great advantage that they occasion no additional valves or attachments to be kept tight. For this it may be well worth while to incur some additional loss of heat. In fact, air-tightness is the great feature of Colonel Beaumont's system. There seems no doubt that he has succeeded in constructing a reservoir into which air can be pumped up to a pressure of 1000 lbs. per square inch, and which will retain that pressure, practically unimpaired, for at least some hours after the operation. At present this reservoir consists of a number of strong tubes, connected by cross-pieces; but another form is now under construction, in the very capable hands of Mr. Daniel Adamson, which is to consist of a welded cylindrical vessel, 3 ft. in diameter, having only one opening for inlet and outlet. This opening is closed, we believe, by a spindle-valve with conical seating, much like an ordinary safety-valve. In any case, Colonel Beaumont must be credited with having seen the advantages to be derived from the use of high pressure, and for having overcome the obvious difficulties attending it. He has made another step in the same direction. Previous employers of very high pressure in the case of steam—*e. g.*, M. Francq., the designer of the fireless engine—have not ventured to turn the full pressure of their reservoir direct on to the face of their piston. They have employed an expander, or reducing valve, to reduce the pressure in an intermediate chamber before admitting it to the engine. It has no doubt been urged by them that, in thus expanding air or steam without doing work no energy is theoretically lost, but in practice it can hardly be doubted that such an arrangement must

produce considerable waste. Colonel Beaumont boldly turns his air at the full pressure of 1000 lbs. into his cylinders, cuts it off almost immediately, and then expands it down, using two or (as at present) three cylinders for the purpose, until he parts with it at atmospheric pressure or thereabouts. The use of these two or three cylinders, no doubt, means a certain amount of complication, and additional loss in friction, &c. The present engine has six cylinders, and the one now building will have four. But there is no reason apparent why two cylinders with cranks at right angles should not suffice, as in M. Mallet's compound locomotive, and then the suppression of the reducing valve cannot but be a step in the right direction.

But giving all possible credit to Colonel Beaumont for the advance he has made in the construction of compressed air locomotives, it still remains to ask how far his system is likely to come into practical use. Any claim on the ground of economy cannot be said as yet to be fully established. It must be remembered that, even if the loss in compression or expansion be completely avoided, there remains an important practical disadvantage, which nothing can overcome. In an air engine there are three sets of machinery which have to be actuated by the boiler steam—namely (1) the engine which works the compressing machinery; (2) the compressing machinery itself; (3) the engine which actually drives the locomotive. In an ordinary steam engine the last named stands alone. There are thus two extra mechanisms in the case of the air engine; and assuming the losses by friction, &c., in each of these to be about one-fourth, the combined efficiency will be diminished, as compared with that of a steam engine, by nearly one-half. When to these we add the losses which must always accrue in compression and expansion, we cease to be surprised that compressed air engines of the best construction do not seem as yet to have achieved in practice an efficiency—or ratio between the work indicated in the driving and in the compressing cylinder—of much more than 30 per cent. Against this Colonel Beaumont has to set two things—first, his own improvements, especially the employment of two or three times the amount of pressure which has hitherto been in use, and, secondly, the fact that his steam is generated in a stationary boiler, and the engine has condenser and all other advantages, and thus far more economically than in the boiler of an ordinary locomotive. Now as to the first claim, we have not as yet the data for estimating its value. As already mentioned, the air for the experimental engine is compressed by the torpedo apparatus at Woolwich, which is a small one, so that the operation takes some hours. In actual work, there is to be a large stationary reservoir always maintained at the full pressure, and having about ten times the capacity of each engine reservoir; and from this the latter will be filled as required by simply making a connection, and with great rapidity. In this process the air will not be doing any work, and the loss due to expansion will doubtless be very small. When this system is fairly started, and not till then, the efficiency of the Beaumont engine will become matter of calculation. As to the second claim, there is no doubt considerable weight in it, but it may be pushed too far. No refinements in apparatus or construction have yet succeeded in reducing the consumption in the best condensing engines much below $1\frac{3}{4}$ lbs. of coal per horse-power per hour. According to Mr. D. K. Clark, the consumption in a good locomotive does not so very greatly exceed this. And although the tramway engine of the future—with which the Beaumont engine must be compared—will be much smaller, and therefore probably less efficient than a locomotive, and on the other hand will not be a condensing engine, yet we think it may be safely asserted that it will be a compound engine, after the type introduced so successfully by M. Mallet on the Biarritz Railway. Recent investigations go to show that for small engines and low speeds the economy of compounding is incontestable, whatever it may be for main line locomotives. Now with a compound portable engine, of very much the same dimensions; and without steam jackets, &c., Mr. Daniel has brought down the consumption of coal below 3 lbs. per horse power per hour. It would appear, therefore, that an economy of 50 per cent. in fuel is the utmost

that can be looked for by the adoption of the compressed air system with stationary boilers, and this will certainly fail to outweigh the serious losses we have already described above.

Probably Colonel Beaumont would not, on the whole, be wise to dwell much on the superiority of his system as far as mere economy of fuel is concerned. But there are several practical advantages which, even for ordinary tramways, he may fairly allege. As against the common locomotive he gets rid of all smoke, all fire, all smell, nearly all noise, all fear of explosion from shortness of water or other neglect, all danger from tubes leaking, feed valves sticking, &c. As against both this and the fireless or hot water locomotive, he gets rid of steam, and with it of the whole difficulty and nuisance of a condenser. Moreover, should an accident occur, there will be no outbursts of scalding steam to spread devastation around. He will also effect an important economy in dead weight, by substituting air for water as the medium in which the power is stored. These are advantages which, even for ordinary tramways, may fairly be set against a moderate increase in the mere consumption of fuel. But there are some cases where these advantages assume an importance quite overwhelming. Such are ordinary mines, where steam and heat are generally forbidden, and where compressed air is already in many instances the recognized motive power; such are underground railways, like those of London; such, above all, are long tunnels, like those of the Alps. The St. Gothard tunnel is a typical example. The whole machinery for supplying the power, including waterfalls, turbines, and air compressors, is there ready on the spot at each end of the tunnel; the engine would merely have to connect itself with this in order to receive its charge, which it would afterwards give out in its passage underground, to the benefit, and not to the annoyance, of the passengers. Here, therefore, there would seem to be a legitimate field for such a system as Colonel Beaumont's, and before long we hope to hear that in this application at least it has obtained such success as it deserves

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RACK RAILWAY WORKED BY ENDLESS ROPES, FOR STEEP INCLINES.

By T. AGUDIO.

From Selected Papers of the Institution of Civil Engineers.

THE plan invented by the author is intended for railways in mountainous districts, for working inclines of 1 in 10, or even steeper, and with curves as sharp as 500 feet radius. This is accomplished by a central rack-rail, and a propelling car or "locomotor," fitted with horizontal driving pinions gearing into each side of the double-faced rack. The ample water power available in such localities is utilized through turbines driving a pair of endless ropes, by which the driving power is communicated to the locomotor.

The turbines, situated conveniently near the foot of the incline, are geared to a pair of main grooved driving pulleys; whence each of the endless driving ropes, after passing round a tightening sheave loaded by a weight, is led up the incline, one on each side of the line, supported at suitable intervals on carrying sheaves, with inclined guide sheaves round the curves. In its course each rope passes also round a pair of large vertical driving pulleys on each side of the locomotor, which drive through friction clutches and miter wheels, the two pairs of horizontal pinions gearing into the rack-rail. At the top of the incline the ropes pass round vertical guide sheaves; and thence return to the foot of the incline by any shorter and more direct cut that is practicable, instead of following the windings of the railway. These endless ropes are accordingly employed, not as ordinarily for direct haulage of the train on the incline, whereby the full strain of the load would be thrown wholly upon them, but as

quick-running driving ropes, for communicating the driving power from the turbines to the propelling mechanism of the locomotor, whereby the strain on the ropes is reduced below that of the load, in proportion as their speed is higher than that of the train. In ascending, the train is pushed up from behind by the locomotor in the rear, and in descending is held in check by it in the front. The locomotor being always at the lower end of the train on the incline, all risk of accident through breakage of drawbars is obviated.

This plan was first tested experimentally in 1862, on the old Dusino incline of the Turin and Alessandria railway—a portion of the line which had been abandoned, owing to the steepness of the gradient, the sharpness of the curves, and the bad ground. The ropes were here driven by steam power; and trials in comparison with coupled locomotives of special construction showed a superiority of 50 per cent. and upwards in favor of the Agudio system. The report in 1864 of the late M. Charles Couche, one of the French commission appointed to investigate the Dusino experiments, was highly favorable to the plan, and he recommended it as deserving of the utmost encouragement from the French government, as it presented such important and indisputable practical advantages over locomotive working, and formed a novel and efficacious expedient for surmounting the natural obstacles encountered in mountainous districts.

Upon the further recommendation of M. Couche, a practical trial of the plan on a larger scale was authorized in 1868. The site selected was on the French slope of Mt. Cenis, where the construction was commenced of an incline of excessive steepness, rising from the valley of the Arc, near Lanslebourg, to nearly the summit of the ridge. The works were interrupted during the Franco-German war, but were resumed in 1872; and the incline was opened for working in 1874, having a length of 1463 yards, or 0.83 mile, and a rise of 1150 feet, from 4730 to 5880 feet above sea-level. The average gradient was thus 1 in 3.82, or 26 per cent., the steepest part being 1 in 3.14, or 31.8 per cent. The incline was laid with a single line of rails, of the ordinary 4 feet $8\frac{1}{2}$ inches gauge, with the rack fixed midway between them.

The rack was made in 2 feet lengths, out of a single flat bar of steel, of $4\frac{3}{8}$ inches $\times$ $\frac{1}{2}$ inch section and 6 feet in length, which was crimped or corrugated transversely while hot in accurately shaped dies under a hydraulic press, so as to form a double rack of 4 inches pitch, and $4\frac{3}{8}$ inches width and height. It was placed on edge, so that the rack teeth facing towards either side were the spaces facing towards the other. These 2 feet lengths were riveted up in sets of three, between the top and bottom bars of shallow channel-iron, each $4\frac{3}{8}$ inches wide by $\frac{5}{16}$ inch thick; and the 6 feet lengths thus formed were strongly bolted down upon a center longitudinal sleeper. The rack was made at the works of Messrs. Brunon, Rive-de-Gier, France; its construction elicted high approbation, and is seen to be much superior in point of safety to the Rigi rack, which is nothing else than a ladder.

The pair of turbines at the foot of the incline were 6 feet in diameter, with 450 feet head of water, and combined nominal power of 900 HP. They ran usually at two hundred and fifty revolutions per minute, and were geared 5 to 1 to the main driving pulleys of 13 feet diameter, giving a speed of 34 feet per second, or 23 miles per hour, to the ropes. These were $\frac{7}{8}$ inch in diameter, of steel wire with hemp core, and weighed 3 lbs. per yard. The strain upon each rope in working never exceeded 2 tons total, or 8 tons per square inch of metallic section. The direction of running was upwards along the incline. The driving power was communicated by their simple adhesion in the grooves of the main driving pulleys and of the locomotor pulleys. The locomotor traveled at one-fifth the speed of the ropes, ascending the incline, therefore, at nearly 7 feet per second, or 5 miles an hour. The pulleys were put in gear with the horizontal driving pinions through friction clutches, for starting the locomotor gradually. With the four pinions working into the rack-rail there were always four teeth in gear, dividing the propelling thrust among them, instead of the whole thrust coming upon a single tooth of a rack having only one pinion gearing into it.

The plain rims of the pinions bore against the flanges of the channel iron bar forming the top of the rack-rail, and thus steadied the locomotor laterally, in conjunction with the flanges on the four carrying wheels. During the ascent four safety-pawls, or catches, clicked into the rack-rail, for scotching the locomotor instantly in the event of accident.

The descent being made by gravity alone, the ropes remained stationary, and the speed was controlled by three powerful brakes upon each locomotor, of which there were two. The first brake applied on starting to descend, and kept on throughout the descent, was a long skid or slipper brake, gripping tightly between its strong jaws the longitudinal sleeper of the rack-rail; the sides of the sleeper were faced with iron bars for the skid to slide against. If more brake power was required, a pair of wood brake-blocks were applied, in one of the locomotors, against a drum on the shaft of each horizontal driving pinion. In the other, a hydraulic brake was employed, somewhat on the dash-pot principle. Each pinion-shaft was cranked, and worked a piston in a water cylinder, with a passage communicating from one end of the cylinder to the other. By throttling this passage to half the area, a powerful resistance was opposed to the rotation of the pinions gearing into the rack-rail. A third resource for retarding the descent was supplied in each locomotor by a pair of vice-plates, between which the rims of the rope-pulleys were gripped laterally, for bringing into play the brake action available from the slipping of the ropes round the pulleys. The second source of brake power was employed sparingly and with great caution, to avoid straining the driving gear; while with the third this was still more stringently the case, to avoid wear of the ropes.

Towards the end of the year 1875, elaborate experiments on the working of the Lanslebourg incline were conducted for more than three months by a commission of the Italian and French governments and of the Eastern Railway of France. During that period the ascent of the 1150 feet rise was regularly performed, with heavy loads, at a speed of about five miles an hour; and the trains were stopped and started at pleasure at any point upon the incline with the utmost readiness and without the slightest jerk. By means of a Prony-friction brake upon the shaft of the rope driving pulleys at the turbines, it was ascertained that the power required for driving the pair of ropes alone, when running empty, amounted to 100 HP.; the locomotor, weighing 12 tons, took 239−100 =139 HP.; and a train of 24 tons, exclusive of the locomotor, required 438− 239=199 HP. The useful effect was therefore $\frac{100}{238}$=45 per cent.; which seemed to the Italian commissioners so much higher than likely, that they reduced it to 38 per cent. by calculating the several resistances of the train from the data furnished by the regular working of ordinary railways.

In a letter addressed last year by Signor Agudio to the Italian parliament, he points out that, even taking the lower figure of 38 per cent. for the above useful effect, this would be equivalent to at least 50 per cent. on an incline of only 1 in 10, less power being then absorbed in raising the dead weight of the locomotor itself. Moreover the old large wagons, out of use, that were lent for the experimental trains, had a wheel-base of no less than 11.8 feet, which was ill-suited to curves of only 500 feet radius; hence the co-efficient of tractive resistance adopted by the commissioners, of only 0.00386, or 8.6 lbs. per ton of load, is far too low; and upon half the length of the incline the resistance must have amounted to ten times as much. For the cheaper construction, too, of the incline, second-hand timber, much damaged, had been procured from the previous Fell railway in that locality. The consequent want of steadiness in the structure, together with the lateral oscillations of the train, contributed to increased friction between the driving pinions and the rack-rail. The commissioners' calculations, again, were based on their earliest experiments, in which the weight of the whole train did not exceed 36 tons, including the locomotor, and the speed was only $6\frac{1}{2}$ feet per second, or $4\frac{1}{2}$ miles an hour; while later on, ten journeys a day were performed with trains of 45 tons total, at a uniform speed of $7\frac{1}{2}$ feet per second, or $5\frac{1}{8}$ miles an hour, both in ascending and in descending. On all accounts, therefore,

the author considers it would be fairer, while safely within the mark, to take 52 per cent. as the useful effect on the incline of 1 in 3.82; which corresponds to 63 per cent. on an incline of only 1 in 10.

The commissioners from the Eastern Railway of France included in their report an estimate of the superiority of the Agudio system over their own most powerful locomotives with eight coupled wheels, working up the steepest gradient practicable, say 1 in 40. The useful effect of those engines is calculated from their coal consumption at 20 per cent. as a maximum; while that of the Agudio system, calculated from its water consumption, is $38 \times 0.80 = 30$ per cent. as a minimum, the turbines utilizing 80 per cent. of the water power expended. An equal expenditure of power would convey 1.8 time as much load up the rack incline as up the locomotive gradient, while the capital outlay on works and plant would be only one quarter as great; hence the Agudio system is estimated to be altogether 7.2 times the more economical.

The advantages of this system for an incline of 1 in 10 are summed up by the author as follows:

1. Nearly twice as much traffic can be worked in a given time as by locomotives.

2. The capital outlay required is little more than one-third. (The French estimate just quoted of only one-quarter was for the steeper gradient of 1 in 3.82.)

3. No inconvenience or delay is occasioned to the working of the regular trains; on the contrary, they would be conveyed up an equal height in little more than half the time and with greater safety.

4. The working expenses are greatly reduced, as the incline of 1 in 10 is only a quarter the length of a locomotive gradient of 1 in 40, and the use of water power saves all consumption of fuel.

5. Steeper mountain slopes can be ascended, and the summit tunnel through the ridge can thus be considerably shortened, or even done away with altogether under favorable conditions of climate and ground.

In a further letter to the Italian Minister of Public Works, Signor Agudio disposes of the objections to the adoption of his system in connection with ordinary lines of railway. He explains in detail the mode of working trains at the junction stations at the top and bottom of the incline, the propelling car there taking its place at the lower end of the train, while the locomotive shunts off into a siding. The rack-rail, standing its own height above the ordinary rails, is made with a tongue to open, like an ordinary switch, where it crosses the main line rail at the junction; while the rope there drops into a narrow slot crossing each of the main line rails obliquely. The propelling car is enabled to run backwards as readily as forwards on the level landings at the top and bottom of the incline, by providing it with an ordinary reversing clutch in the driving gear, the ropes continuing to run always in the same direction, upwards along the incline. For working regularly trains of 180 tons useful load, a steel wire rope weighing 3 lbs. per yard, and running at the same speed as at Lanslebourg, would suffice for a rise of about 2300 feet, which would give nearly $4\frac{1}{2}$ miles length for an incline of 1 in 10. Without any reduction of load, a slight increase in the size of the rope or in the speed of running would allow of the incline being extended to 6 miles, thus giving a rising of 3000 feet. The system thus lends itself with great readiness to the various requirements of railway routes. As the ropes do not act by direct haulage, but drive by simple adhesion in the groove of the locomotor pulleys and through a friction clutch, any sudden increase of train resistance throws no severe strain upon the ropes, but merely causes them momentarily to slip on the pulleys at the first instant; and the slipping then transfers itself immediately to the friction clutch, which is adjusted beforehand to slip whenever the pull upon the ropes rises only 10 per cent. above their normal tension in regular working. Repeated experiments equivalent to actual breakage of the ropes at Lanslebourg showed that the ascending trains were instantly scotched dead at any point on the incline, by the four catches clicking into the rack-rail, without any occasion to apply the brakes. Failure of one of the pair of ropes would not delay passenger trains, which

could be worked by the other rope singly while the broken rope was being spliced.

Signor Agudio urges the adoption of his system for the ascent of Tivoli, about 16 miles from Rome, on the projected Rome, Aquila and Solmona railway where a short cut can be made by a rack-rail incline of only 1¼ mile length, with a ruling gradient of 1 in 10, and curves not sharper than 1,000 ft. radius, in place of a loup five and a half times as long, which would be required for the proposed locomotive gradient of 1 in 70, the total rise being 500 feet. The cost of the work is estimated at about £ 20,000 for the entire construction of the incline, laid with a single line of rails of 4 feet 8½ inches gauge, with the rack-rail between them; £ 2,400 for two pairs of steel wire ropes weighing 3 lbs. per yard, one pair to be kept in reserve; £ 8,400 for driving pulleys, tightening, guiding, and carrying sheaves, &c., with a sufficient supply of duplicates in reserve; £ 5,000 for three 12-ton locomotors; and £ 10,000 for the hydraulic power, including two pairs of turbines of 1,000 HP. in the aggregate, one pair to be in reserve for emergencies. Adding for contingencies and superintendence, &c., the total estimate amounts roundly to about £ 56,000. Trains of 180 tons would make the ascent or descent of the incline in ten minutes. By the adoption of similar inclines at other points on the same line of railway of 100 miles in length, 30 miles might easily be saved out of the heavier portions of the works, and shorter tunnels would suffice.

WATER SUPPLY.

From "Nature."

Among the improvements in sanitary matters that this generation has witnessed not one ranks higher than the settled and still growing conviction of the importance of a pure water supply; and nowhere are the various aspects of the question more keenly debated and considered than in the Metropolis at the present time.

At a discussion at a recent meeting of the Chemical Society there seems to have been some doubt thrown on the conclusions arrived at by chemists in determining the wholesomeness of a water, by no less an authority than Prof. Huxley, and it may be well to inquire how far his allegations are borne out by facts.

In the earlier days of the history of chemistry, as was to be expected, the processes adopted in the analysis of water were crude in the extreme, and the quaint ideas promulgated in the treatises then published are not a little amusing. Gradually, however, and especially during the last few years, the methods of analysis have improved, and although, judging by the wide diversities of opinion that exists as to what may or may not be pronounced a water sufficiently pure for drinking purposes, the subject cannot yet be said to have arrived at a stage completely satisfactory; still, so far as the purely chemical evidence is concerned, it would seem to be able to furnish results which are sufficiently exact for all practical purposes. The operations involved are among the simplest and easiest the chemist has to perform, and consequently it is not the data furnished by analysis that are called in question, but the conclusions drawn from them.

Persons interested in sanitary questions, but who have no special knowl edge of the difficulties that beset the forming a correct judgment as to the wholesomeness of water, are apt to express themselves as scandalized, and it must be confessed with some show of reason, that it should be possible there should be so little agreement amongst those who are looked up to as authorities on such matters.

This disagreement, however, is more or less inevitable in the present state of our knowledge, and is largely due to the intricacy of some of the problems involved in the question, which is by no means a simple chemical one.

The debatable ground is the nature and estimation of organic matter, and the amount of significance that should

be attached to the presence of oxydized nitrogen compounds.

Organic matter may be of animal or vegetable origin, the former being dangerous and the latter much less so, if, indeed, it be not altogether innocuous. To distinguish between the two kinds is therefore all important; but unfortunately it is impossible directly to do this, as both animals and vegetables yield albuminoïd matters, which are, chemically speaking, practically identical in composition.

Of the various processes for the estimation of organic matter there are three that are in general use. One, the oldest, known as the permanganate process, finds its advocate in the present day in Dr. Tidy, and consists in measuring the organic matter by the quantity of oxygen required to oxydize it. Another, originated by Prof. Wanklyn, and which he calls the albuminoid-ammonia process, consists in decomposing the organic matter by an alkaline solution of potassium permanganate, and taking the resulting ammonia as the measure of the organic matter. The third process, the one employed in the laboratory of the Rivers Pollution Commissioners and advocated by Dr. Frankland, its originator, estimates the organic carbon and nitrogen separately.

A good deal may be said in favor of all these processes, as affording a rough estimation of the quantity of organic matter, but none of them can be relied upon as giving any indication of its nature, *i. e.*, as to whether it is dangerous or not; and yet it is the almost invariable custom to judge of a water by the quantity of organic matter it contains, no matter what its origin, and a variation of two or three times a given amount is held to make the difference between a good and a bad water.

It was to this point that Prof. Huxley especially addressed himself in his remarks already referred to. He gave it as his opinion, speaking as a biologist, "that a water may be as pure as can be as regards chemical analysis, and yet, as regards the human body, be as deadly as prussic acid, and on the other hand may be chemically gross and yet do no harm to any one." "I am aware," said he, "that chemists may consider this as a terrible conclusion, but it is true, and if the public are guided by percentages alone they may often be led astray. The real value of a determination of the quantity of organic impurity in a water is, that by it a very shrewd notion can be obtained as to what has had access to that water."

However startling these statements may be to those who judge of the wholesomeness of a water by the amount of organic matter it may contain, we believe it to be none the less an accurate description of facts. It is within our knowledge that some of our most wholesome supplies sometimes contain an excess of organic matter, and that the waters which give rise to typhoid fever, and other hardly less serious disorders, are frequently just those which contain the least, the difference of course being that in the one case the organic matter is innocuous, in the other deadly.

Since, then, chemical analysis fails entirely to distinguish between these two kinds of matter, it may be thought to be a work of supererogation to have recourse to it at all. Not so, however, for what analysis fails to do directly it can to a large extent do indirectly. Organic matter in solution in water is more or less prone to oxydation, the highly putrescible matter of sewage being most so, and that derived from vegetation very much less so. Hence it follows that one would expect to find the oxydized nitrogen compounds in greater excess in the one case than in the other, and as a matter of fact that is just what we do find. Almost invariably, in all waters of acknowledged wholesomeness, the quantity of nitrates never exceeds a certain small amount, whereas in waters, such as polluted well and spring waters, that have given rise to illness, the oxydized nitrogen compounds, with other accompaniments of sewage, are to be found in excess. By means then of these oxydized nitrogen compounds we get collateral evidence throwing light on the nature and probable source of the contamination, of which a mere percentage estimation of organic matter would fail to give the slightest indication.

The mistake has been hitherto, that the discussion has been narrowed by looking at the question almost entirely from a chemist's point of view. It is, however, to the biologist that we must look

chiefly for the future elucidation of the subject, and he has a field of the widest range, embracing much untrodden ground, for his investigations.

Putting on one side the specific poisons which, through the medium of water are able each to generate, after its kind, diseases such as typhoid fever, it is highly probable, judging from what has already been proved to take place in analogous cases, that dangerous organic matter is not poisonous as such, but acts by affording the pabulum for organisms which are able to set up putrefactive changes in the blood of the person drinking polluted water. Even the conversion of organic matter into nitrates is not a mere chemical process of oxydation, since we now know that the oxydation only takes place by the help of a distinct ferment.

In the inquiry as to how far organic matter is destroyed in rivers, it is clearly insufficient to rely upon laboratory experiments in which diluted sewage is exposed only to the oxydizing influence of air. This is entirely to ignore the agency of vegetation and of the vast army of organisms, identical with or allied to bacteria, which, being endowed with various functions of reorganization, convert the carbon and nitrogen of organic matter into simpler inorganic compounds, these in turn to become the food of the more highly organized aquatic vegetation.

Whilst therefore duly recognizing the practical help that chemistry can afford in the more limited scope that properly belongs to it, we trust, in the interest of sanitary science, that the enunciation of the views of so distinguished a biologist as Prof. Huxley may have their due weight with those to whom these questions are ordinarily referred, and will tend to promote a better understanding and more solid ground for agreement than has up to the present seemed possible.

THE IRON CRISIS AND ITS LESSON.

From "Iron."

At a time when the iron industry, by far the most important of English manufactures, seems fast relapsing (notwithstanding fitful gleams of activity) into the critical position out of which it only emerged some eight months ago, it is clearly well worth our while to attentively examine our position and see if there is any prospect of mending it.

We have had more than enough of rosy prospects and pæans over the good things that are to come in the future, but are unable to fill the exchequer in the present. The most mischievous things in the world are agreeable illusions, and the best service is to expose them promptly. That we can look to any concurrence of favorable circumstances bringing about a proximate renewal of the brief season of prosperity and high prices, which came upon us with bounds and "booms" in the latter part of last year, seems to the unbiased observer in the highest degree improbable. America has been lately looked to as being, and likely to continue to be, our best customer for iron and steel, and the American demand is the sheet-anchor of our optimists; but that the working blast-furnace capacity of America, with her 400 furnaces in blast, is now very nearly, if not quite, abreast of all possible demands from American iron consumers seems indisputable; while it is also pretty clear that the Bessemer and open-hearth steel production of the United States will, in 1881, be not far, if at all, short of fifteen hundred thousand tons. The works of the Pittsburgh Steel Company and the St. Louis Works, with the extensions of the North Chicago, Scranton, Pennsylvania and the Edgar Thompson Companies will, without the new open-hearth plants now building, be alone equal to an increased product of at least 300,000, and probably 400,000, tons of steel a year, while the new open-hearth furnaces will add a further 250,000 tons to the supply, so that clearly this is not an exaggerated estimate. Now the rail requirements of the States for 1880-1881

are not, by the most competent observers, expected to exceed 1,400,000 tons. It is therefore evident that, unless some new feature arises in the calculation, there is not much to be hoped for in the way of rail orders from the States during the coming year. Certainly the demand for iron rails will not be renewed. There remain only the home, European and colonial markets. But here we are brought face to face with another danger. We have been so long accustomed to consider our position as makers of cheap iron and steel unassailable, that we have perhaps allowed ourselves to slacken speed in the technical race, while our opponents have been straining every nerve to cheapen production, and availing themselves of every improvement that holds out a promise of economical results. It is certain that unless we bestir ourselves we may find Continental steelmakers underselling us in neutral markets to a far greater extent than has hitherto been regarded as possible. In Italy and Spain and Holland we have already had to encounter severe competition from German and Belgian and even French makers. Let us by all means open up new markets in China and Japan, Turkey and Persia; but while thus going far afield it will not do to neglect what is nearer home. If the iron trade of England is to regain a position of prosperity it must, before all, devote itself to economy in production, and not sit quietly by and trust to Providence and a rise in the markets. In pig-iron making, it is generally admitted that, in our newer districts at least, such as Cleveland, we are in the front rank for technical and economical efficiency; though, even here, the Americans, with their 1100 tons per furnace per week have surpassed anything we have yet done, and the Eastern France and Belgian and German makers are pushing ahead both in outputs, such as the 750 tons per furnace per week which is not uncommon in Luxembourg, and in economy of fuel. There are now several districts in Europe where pig is made as cheaply as in Cleveland, and that to the amount of some hundreds of thousands of tons per annum. It must, however, be admitted that the margin for economizing in blast-furnace practice is not large, and that, with the general adoption of the regenerative stove, we are doing much to minimize that margin. When we come, however, to the conversion of pig iron into malleable products, the matter is quite otherwise. At the present time it is best boldly to face the fact that the main, if not the only, direction in which economy of manufacture is to be looked for is in the substitution of steel for iron in every department. It cannot be too clearly understood that with modern appliances, which admit of readily producing from a pair of Bessemer vessels 80,000 to 150,000 tons a year, or with a pair of large Siemens or Pernot furnaces 20,000 tons a year, it is very much cheaper to convert a ton of pig into steel or ingot iron than into puddled iron. The elements of the calculation are simple. The two great factors of cost in the conversion of pig into malleable iron are labor and fuel. In each of these items the costs of a well-appointed Bessemer work, with a good system of boilers and economical engines, are far less than half of those of a puddling furnace. The fuel consumed in the Bessemer process is indeed a mere fraction of that consumed in puddling, while the resulting metal is unquestionably far better for every purpose than anything that can be turned out by the puddler. Yet we find almost every one of our leading competitors doing more—taking account of their crude iron manufacturing capacity—than ourselves, in substituting steel plant for the wasteful and obsolete puddling furnace. To illustrate this we may take the case of America, France, Belgium and Germany. The make of pig iron in 1879 in the United States was about 2,700,000 tons. The capacity of their new steel plant, according to Mr. Swank, is 570,000 tons, of which 330,000 will be Bessemer. In other words, their new Bessemer steel plant is now capable of dealing with one-eighth of their total production of pig iron. Moreover, their total steel-making capacity for 1881 will be (as we have seen) at least 1,500,000 tons, that is, they can more than convert half of their total pig production into steel.

In France the new Bessemer works of Longwy, de Wendel, Denain and the Meuse, alone will have a capacity of 200,000 tons, without reckoning the

large open-hearth extensions at St. Chamond, Terrenoire, and elsewhere. But the total product of pig iron in France is only 1,300,000 tons, so that our neighbors, at whose claims to be a great and enterprising iron making people we are accustomed to sneer, are preparing for the change by building new Bessemer works, which will take at least a seventh of their total make of crude iron. Belgium is erecting new Bessemer plant which will have a capacity of over 100,000 tons, or say one-fourth of her total makes of pig iron. Lastly, notwithstanding the almost crushing disasters which overtook her iron trade two years ago, we have Germany, with a pig-iron production of 1,900,000 tons, not only increasing her open-hearth capacity, but building at least four new Bessemer works, to work up her cheap phosphoric irons into steel. The capacity of these works may be taken as at least 150,000 tons, which represents about one-twelfth of her pig-iron production. In England we have four new vessels building at Bolckow, Vaughan's works, two at Erimus, and two at Darlington, and one at Rhymney, with a total capacity, according to Mr. Jeans, of say 155,000 tons—we do not count the Carnforth plant, which is really an old one, though it has never been at work. The same remark indeed also applies to the Darlington plant, which is actually only a part of Bolckow-Vaughan's old Gorton plant, and is therefore not a real addition to our steel works, but merely a change of locality of an old work. This correction reduces the productive capacity of our new Bessemer plant to 125,000 tons, or in other words our new Bessemer plant will not convert one-fiftieth of our total make of over six and a quarter million tons of pig.

It is therefore clear that of all great ironmaking countries, we are at present the slowest in enlarging our productive capacity by the most economical and advantageous of all metallurgical processes. In fact, even Austria, with her four new ten-ton converters, which alone could convert at least a seventh of her make of crude iron, is far ahead of us in enterprise. But it may be urged that our existing Bessemer plant was far from being utilized in 1879, and why then should we build more; and secondly, that the large initial expenditure to erect a Bessemer plant is a serious obstacle when the profits of the trade are so precarious and small, and trade is so bad as it is at present. Both these seemingly plausible pleas, however, are fallacious. The existing British Bessemer plant that was not fully used in 1879, was only not used because it was old and badly arranged or badly placed. No better evidence of this can be afforded than the fact that the idle plants were, with one exception, those of the earlier days of the Bessemer industry, when two hundred tons per pit per week was thought an enormous output, and all arrangements were made in accordance with that view. To expect a Bessemer plant built more than a dozen years ago to compete successfully with those of to-day, when we consider the enormous progress the Bessemer process has made in the interval, would be utterly unreasonable. It is therefore not to be wondered at that some of the old plants with their three or four hundred tons per week capacity, should have been withdrawn from competition with the more modern plants which, casting comparatively little more, have four times their capacity. A modern ten-ton Bessemer plant of the Holley type, costing from £30,000 to £45,000, according to locality, has been proved capable of producing at least 140,000 tons a year, and would probably make much more, and is without question the cheapest iron making plant in the world. Forty thousand pounds seems a large sum, but when we find the interest and sinking fund on this capital outlay amounts to less than ninepence per ton on our product, while it appears in addition that the ironmaking value of each man and each ton of coal is increased many fold in comparison with its utmost possible effect in puddling, we see what the President of the Iron and Steel Institute means by his assertion that the Bessemer vessel is the cheapest converting apparatus in the world. There is, however, one other limitation which has hitherto done more than anything else to arrest the progress of steelmaking, and that has been the presence of phosphorus. So long as we were confined to the use of an insignificant fraction of our pig iron for steelmaking there was

an obvious limit to expansion. But the final complete success of the Thomas-Gilchrist dephosphorizing process has removed the last bar to an indefinite extension of our steel trade; and, if we would not meet the fate of laggards in the industrial race, we must make haste to bring our steel producing capacity into closer approximation with our crude iron production. That we have sufficient ground for assuming that the lime process is an economical success, as well as a technical one, will probably be recognized by those who have learnt from our foreign columns from week to week the remarkable development which this process has attained on the continent—where, after a protracted trial at five of the leading Continental works, not only have these finally adopted it, but at least seven or eight new works are being built for its employment. Whether, as its extreme advocates assert, it will cost no more than the ordinary Bessemer process, or whether, as its interested opponents maintain, the actual working costs will exceed by seven or eight shillings the normal Bessemer costs, does not much signify for our purpose; since it is clear that, for the past twenty years, the difference between hematite and phosphoric pig has always exceeded thirteen shillings, and averaged about thirty shillings. We have specially mentioned the Thomas-Gilchrist process because it is, as far as we know, the only direct dephosphorizing process, which has obtained any success at all; certainly no other has so far been employed for the manufacture of over 20,000 tons of steel. The Krupp or Bell process has, however, of the indirect processes, though not applicable to the Bessemer operation, in preparing pig for treatment in the open-hearth furnace—obtained a certain degree of development and success. It appears, however, that it has been entirely abandoned in Europe, though it is, or speedily will be, in work in America. It will be interesting to observe the relative success of the direct-*lime* (or Thomas-Gilchrist) Siemens process, which, we understand, has already been practiced considerably in France, and will soon be in operation in America and England; and the indirect-*ore* or Bell-Krupp-Siemens process, which will unquestionably have a fair trial in the States, under Mr. Holley's auspices. How great is the confidence of French ironmasters in the technical future of dephosphorizing is shown by the fact, announced by us some weeks since, that M. Schneider and his associates, whose experience of the lime process is very considerable, they being, we believe, among Mr. Thomas' earliest licensees on the Continent, have already contracted for delivering nearly a quarter of million of tons of steel rails, the greater part of which must necessarily be of dephosphorized steel. It is not, however, into rails only (or even chiefly), but into angles, plates, girders, and merchant iron of every description, that we must look to transforming our steel. It is very certain that for all these purposes steel, and cheap steel, will be wanted in immense quantities, and iron will not be accepted by foreign customers, if Continental and American makers are able to supply them in steel cheaper and better than we can in iron. Unless we wish to sink as ironmakers to the position of hewers of coal and makers of pig iron for other nations, and nothing more, we must speedily recognize, in a practical English way, the fact that steel is not only superior to iron, but, when made by good plant on a good system, also cheaper to produce. This we take to be the lesson of the times, and the sooner we master it the better.

THE FORTH BRIDGE.—Operations are proceeding rapidly for the erection of the Forth Bridge. Workmen are engaged on Inchgarvie erecting a brick and concrete platform, on which to place instruments for the purpose of making accurate measurements of the heights, widths and depths of the various works connected with the undertaking. At South Queensferry the contractor is constructing enormous engineering, iron-founding, and fitting workshops, in which steam cranes and other powerful appliances will be placed. These "shops" are connected with the railway by means of a branch-line. The proprietors of houses, ground, &c., on the line of the bridge and railways have been served with notices to lodge their claims for compensation within twenty-one days. On the north side of the Forth matters are progressing.

THE TRAVELING OF SEA BEACHES.

By GEORGE HENRY KINAHAN, M. R. I. A.

From Selected Papers of the Institution of Civil Engineers.

Two of the chief points of controversy as regards this subject are: 1st. Whether wind waves or tidal currents are the principal moving agents in the traveling of sea beaches? and 2d, Whether large stones can be carried by ordinary ocean currents in deep water? During the last twenty years the author has had opportunities of observing the Irish Sea beaches, and especially during the last six years, while stationed in the counties of Wexford and Wicklow. The following is a digest of the results of his observations: Off the south coast of Ireland the flow wave runs eastward, and off the east coast northward. The flow-tide generates three classes of on-shore currents: 1st, on-shore currents running in a direction generally similar to that of the flow-tide wave; 2nd, counter tides, or on-shore currents, flowing in a contrary direction to that of the flow-tide wave; and 3rd, half counter-tides, or on-shore currents, generated at many of the headlands a few hours before high water. In some places the half counter-tides may run in a contrary direction to the normal currents, and in other places to the counter tides. All these on-shore currents, especially the latter, carry the beaches with them under ordinary circumstances.

The wind waves are of two kinds, viz., ground swells, or waves generated in the Atlantic or Channel, and waves due to the winds blowing directly on the coast. Their effects are either to pile up and fill the beaches, or to cut them out. The ordinary wind waves assist the flow-tide currents when they are going in the same, or nearly the same, direction with those currents. If they strike the beach at a right angle, or nearly so, they pile it up, forming "fulls" and "storm beaches"; while, if they are coming in a more or less opposite direction, they cut out the beach. On the east coast, winds blowing from any points between S. and E. S. E. by E. accelerate the traveling of the beach. From E. S. E. by E. to E. N. E. the beach is piled up; while between E. N. E. by E. and N. the beach is cut out. The cutting out is due to the dancing waves generated by the meeting of the tidal current and the wind waves. These toss and churn up the sand and other detritus, causing it to be carried out by the backwash into deep water. Continuous heavy winds in the same direction as the flow-tide currents will accelerate the carriage of a beach to such a degree that every particle of it may be carried with the tide: thus leaving the up-stream portion of a beach empty, while a "full" is formed at the down-stream end. Ground swells act differently from ordinary wind waves, as they break on the coast line perpendicularly, or nearly so, with an undulating or rolling motion, which generates a considerable suck or backwash, that cuts out the beaches.

The following is a summary of the general effects of the winds on the beaches of the east coast, between Carnsore and Dalkey:

W. and S. W. winds generate ground swells, which usually cut out the beaches. In places they drift the sand from the land out to sea or on to the beaches.

S. winds in places cause "fulls" at the northern ends of the strands, due partly to the rapid carriage northward of the beach, and partly to the land driftage of the sand, &c. They often generate ground swells.

S. E. winds carry away the southern ends of the beaches to fill them in at the northern end. At Poulduff (Cahore), it is said two strong twelve-hour gales are sufficient to cut out and carry north the "fulls" south and north of the pier.

E. S. E. by E. to E. N. E. by E. winds generally heap up the beaches. In places, however, on account of being oblique to the direction of the flow-tide current, they in part cut out, forming transverse ridges on the beach. The flow-tide waves drive up detritus to strand it, while the wind waves suck it out. To form this class of beach the wind waves are not so effective as the

tidal current, and the detritus is more stranded than removed; so that while the wind lasts the strand fills.

N. E. winds cut out the northern portions of the beaches, while they sometimes "full" the beaches to the southward. The most remarkable "fulls" due to these winds were in the small bay to the southwest of Kilmichael Point, and the "storm beaches" in the Wicklow and Bray strands. In the first locality, after continuous winds from the northeastward during the spring of 1876, a foreshore was formed over 200 yards wide, at the base of a cliff, where during the previous winter there was deep water.

With N. winds, no direct influence was observed, except that they seemed to retard the flow of the tide up the Irish Sea.

These results are connected solely with the normal currents flowing in a nearly similar direction to the flow-tide wave. With the counter tides and half counter tides the results are necessarily different, in accordance with the directions in which they may be running. Wind waves combined with half counter tides, always give maximum results, on account of the tide being nearly full, and also because the waves are larger and have greater power.

Ground swells with flow-tides usually cut out. They sometimes form transverse ridges, or beaches similar to those due to easterly winds, but in these cases the cutting out is generally in excess. Ground swells at the beginning of the ebb tide sometimes cut out, especially near Courtown, where the rise and fall of the tide is only a few feet. Ground swells with E. winds sometimes seem to assist in filling in the beaches, but with N. E. winds they cut out. Ground swells with the counter tides cut out the beaches. Ground swells with the half counter tides, that run east, fill in the beaches.

The cutting out due to ground swell or contrary winds is quite distinct from that due to a S. E. or any favorable wind, as the latter carries the beach along the strand from one place to another, while the former suck out the beach into deep water. Ground swells due to S. winds usually break on the shore nearly as quickly as the ordinary waves; but the ground swells due to S. W. and W. winds have intervals of one, two, five, or more minutes between them, and are much larger than the ordinary wind waves, or the tidal waves, which may be breaking at the same time, rise much higher on the beach, and often at one sweep carry away a mass of materials that it has taken a number of small waves to pile up.

Beaches may be clean swept and left empty: (1) By the tidal current alone, if for a long time there are not any contrary storm waves to stop the traveling of the beach; (2) If there are continuous winds that accelerate the traveling of a beach; or (3) If there are continuous winds that cut out the beach. In any of these cases, if the strand is left empty and a storm comes on, the marginal cliffs are left unprotected and may be rapidly denuded, a small storm having greater power when the beaches are empty than a great storm if the beaches are full, and winds which are most destructive to the beaches may have little or no effect on the marginal cliffs. The best section of a beach to preserve a marginal cliff, is one having below a slope, next above a flat or cess, higher up a second slope, and above all a second flat. Such a section is not common; full beaches more often having a slope below, and a wide flat above. The largest denudation of the coast line is north and south of Kilmichael Point.

CARRIAGE OF STONES IN DEEP WATER.

If a point a few miles from the shore in from 15 to 20 fathoms of water be chosen, and fixed by bearings, and examined regularly at low water during calms, it will be found that the stones at the bottom of the sea are always changing their position; some being carried away, while new ones are drifted on to the observed ground. On the coast of Galway, in many of the small strands, large blocks, some weighing 2 or 3 cwt., will be stranded after storms, which blocks must have traveled through water 15 or more fathoms deep. At the west end of Tacumshin Æolins sand ridge, there is below the sloping shingle beach a nearly flat sandy strand, usually free from blocks, which, on April 4, 1876, during low water, after a heavy gale from the southwest, was covered with

blocks, having deep seaweed attached, while on the slope there were other similar blocks. As the tide rose, these blocks began to drift landward, and in twenty-four hours nearly all the blocks were collected in horizontal lines. Numerous observations also proved, that blocks can be drifted in a considerable depth of water; not by the simple impulse of the currents or storm waves, but by such action combined with the buoyancy given to the stones by the growth of seaweed attached to them; and in case of small stones, it can easily be seen, during any gale, that the floatage of attached seaweed is often greater than the weight of the stones. With large stones, therefore, it would only be necessary that the stone—no matter what its size, if sufficient seaweed be attached to make it buoyant—should be loosened out of its bed of sand, to allow it to be carried and suspended in any current into which it might be drifted. In deep water the buoyant stones would be gradually and slowly drifted by the tidal currents; but after they come under the influence of the action of the storm waves their carriage would be more rapid.

ON THE HARDENING OF STEEL

By WILLIAM GALBRAITH.

From "Engineering."

At the close of last year there was a considerable amount of correspondence in your journal on the hardening of iron and steel, which was followed in the beginning of the year by the very able paper on the same subject taken as read at the Liverpool meeting of the Iron and Steel Institute, by Professor Akerman, and while it might be supposed such a paper would increase the interest on the subject the correspondence entirely ended there.

As one of your correspondents on this subject at the end of last year, I beg a little space for the consideration of one or two points in the correspondence, and in Professor Akerman's paper, which I think worthy of some attention.

I think it would be well to state first of all the facts which are known concerning the matter, at least as I stated them in my letter in *Engineering* of December 12, 1879. These are:

1. The carbon in steel is in combination both before and after hardening.

2. The per centage of carbon is neither increased nor decreased by hardening.

3. The specific gravity of steel is less after hardening than before.

The first two are, of course, "negative" facts, and it is because they are disputed that I find it necessary to mention them. With regard to the first of them, Professor Akerman draws attention to the probable existence of carbon in a third state in iron or steel, as a carbon existing in a form something between graphite and combined carbon, what he calls cement carbon.

This state of carbon, however, if it does exist, will not at all approach the diamond form, as some of your correspondents suppose, although I know it is a theory largely held in Sheffield, the reasoning of which perhaps might be obvious to some people, but it certainly does not commend itself to the scientific mind.

In all my experience in the analysis of irons and steels, I have never noticed anything to give the slightest coloring to the theory of the carbon being converted into a third form when slowly cooled from a high temperature. We certainly know that an iron or even a steel containing a large per centage of carbon, may be made to separate some of its carbon in the form of graphite if slowly cooled, and to take it up again if heated and rapidly cooled, but in all such I believe it to be distinctly graphite, or rather uncombined carbon, which separates. It is true I have sometimes noticed a block of insoluble residue when blister or cement steel is treated with nitric acid, but I have always found the residue to be slag, which is always present in the bar iron used, and hard-

ening makes no difference in the amount of this deposit or residue, and while Professor Akerman quotes M. Caron's and Herr L. Rinman's experiments in proof of the reverse, he seems painfully conscious that they are not at all conclusive, for he adds, "but until hardening and cement carbon can with certainty be distinguished, and some method has been discovered of quantitatively determining each of them, it is of course still too early to say anything with certainty on this point."

If it is true that the cement carbon is left insoluble when treated with hydrochloric acid, while what he calls hardening carbon is given off with the hydrogen, I do not think there ought to be any great difficulty in determining them, as the problem would simply be a question of determining the carbon left behind, and that given off, a question which would present no great chemical difficulty.

If, however, it is a question of the "quantity of carbon remaining undissolved when steel is dissolved in cold hydrochloric acid" being "very different, according as the same steel was differently treated before dissolving," the difference in the amount of carbon undissolved must be out of all proportion to the difference between the hardened and unhardened steel.

For example, if a steel containing 1 per cent. of carbon leaves a residue of carbon when treated with acid equal to 2 per cent. of carbon, and on hardening leaves a residue equal to 1 per cent., it surely cannot be argued that the difference (1 per cent) should make such a complete difference in the steel as exists between it when in the hardened and unhardened state; and it must be remembered that any steel will give off a large per centage of its carbon as carburetted hydrogen on being so treated, and I may add that a varying proportion is given off according to the conditions or circumstances, *i. e.*, the temperature and strength of the acid, the size of the pieces of steel treated, &c., and if such conditions can sensibly affect the quantity of carbon left insoluble, or given off with the hydrogen, I think it is to be inferred that the molecular condition of the steel should also influence it to a considerable extent, and I will presently show that the molecular condition of the same steel when hardened or unhardened is very different. In fact, I consider Herr Rinman's and M. Caron's experiments to be rather a proof of this, than that the carbon exists in two separate forms in steel.

Another of your correspondents brings up a similar argument to Professor Akerman's, namely, that two steels of the same per centage of carbon behaved differently on treatment with nitric acid, but he omitted to say that the one was hardened and the other was not, or that the conditions of such treatment were identical.

Again, another argument which Professor Akerman advances is that if hammering or rolling makes the steel more dense, and, therefore, he argues, forces the carbon into combination, quenching the water ought to do the same: but as hardening or quenching has the very reverse effect, namely, lessens the density, the argument must fall to the ground; but I shall dwell on this point further on.

2. With regard to the second fact, namely, that there is no *loss* of carbon when hardening, Professor Akerman of course acquiesces in, but it is exceedingly difficult to remove the reverse impression, which is probably due to the loss of weight by scaling. In connection with this I quoted in my last letter some of Mr. Wrightson's experiments in proof of it, yet one of your correspondents disputed my interpretation of the experiments. Of course they speak for themselves, but my conclusion is the same as Mr. Wrightson's, for he adds, "Thus sufficiently accounting for the discrepancy between the specific gravity and the change of volume by scaling." See *Engineering*, October 10, 1879, page 284.

3. The specific gravity is less after hardening than before.

It has been a matter of the greatest surprise to me that Professor Akerman should have so completely omitted all reference to this well-known fact, more especially as I believe it is one of the most important in connection with this question, and it seems to me that an acceptance of the fact will completely upset Professor Akerman's reasoning; in fact nearly all his reasoning so based

on the assumption of the reverse being the truth.

I have taken the specific gravity of steels and irons as follows, simply for the purpose of verifying what is undoubtedly a known fact:

	Specific Gravity. Not Hardened.	Specific Gravity. Heated to 250° C. and Hardened.	Specific Gravity. Heated to 270° and Hardened.	Heated to Redness and Hardened.
Iron	7.636	..	..	7.623
"	7.504	..	..	7.471
"	7.620	7.609	..	7.605
"	7.613	7.605	..	7.603
Soft steel or ingot iron, 1 per cent. carbon	7.824	7.818	..	7.815
Cement Steel	7.627	..	7.587	7.432
"	7.588	..	7.568	7.560

These figures show conclusively the difference in specific gravity, and that the higher the steel or iron is heated the greater is the difference, and the cement steels when quenched at 270 deg. C. were *distinctly hardened.*

They also show that the difference in the specific gravity is greater in the case of steel than of puddled or ingot iron. In order that my remarks on this point might be perfectly understood:

"That first of all a *violent compression* must in such a case take place is self-evident, for we have now to do with a body heated from without, which therefore, at least when the heating has not been of all the longer duration, is apt to be warmer in the outer than in the inner layers. When now this body by dipping in a hardening fluid, or in some other way is exposed to a rapid cooling acting from without, the outer layers are cooled first, and the difference of temperature between the outer and the inner layers is greater the whole way through in the same proportion as the method of cooling is more powerful. But *the cooling is accompanied by contraction or compression*, and the more the outer layers have been cooled in proportion to the inner, with the *greater compressing* force must the former react upon the latter, which by the resistance react upon the outer layers." The italics are mine.

In support of the above, Professor Akerman uses arguments which I at least confess I do not understand, and assumes certain things to be well known facts, which I think are not quite admitted to be such; for example he says, "Burnt iron, as is well known, is the name given to an iron which through long-continued or strong heating has had the opportunity of assuming a crystalline texture, with the brittleness which accompanies it on account of the diminished cohesion of the crystals."

This letter is quite long enough already, otherwise I might dwell on this further, but I do not think Professor Akerman will defend it, nor do I think it quite admitted that "the more carbon, and in particular the more phosphorus it contains the greater is the liability of the iron to be burnt."

Let us suppose a piece of steel to be heated, and let us follow what takes place: First, then, it expands, and if allowed to cool slowly will come back to original size, minus loss by scaling. Plunge it suddenly into cold water, however, and I think the probability must be admitted that it does not get time sufficient to get back to its original state, we therefore get what he calls the *status quo* condition so far, but Professor Akerman omitted to say that this condition meant that the specific gravity was decreased, a point which I have noticed before.

But here the *status quo* condition ends, for as the steel is heated the molecular vibration increases, but this vibration is at once decreased or stopped on cooling: the molecules are suddenly arrested in their vibrating motion, and are left in a state of tension, in a condition in which they ought to have greater vibration, and the temperature too low for their distance apart.

I think the fact of the decrease of specific gravity would of itself dispose of Professor Akerman's statement that "its cooling is accompanied by contraction or compression;" but we have another fact which I think is quite as conclusive, and has a special bearing on this part of my subject.

Suppose a bar of iron or steel to be heated, and the lower part of it quenched in water. If Professor Akerman is right, it ought to be bent in such a way that

the top of it would be convex, and the bottom in the water concave; but Mr. Wrightson in his paper on "Iron and Steel at High Temperatures," read at the same meeting of the Iron and Steel Institute, shows that the very reverse is the case.

I dare say it might be asked now, "But if iron acts in the same way as steel if its specific gravity is decreased when suddenly cooled, &c., why does it not harden as steel does?" Well, it will be noticed first of all that the difference in specific gravity in the case of iron is not so great as in the case of steel, but still the difference is such that it cannot be given as the only reason, and we will find the explanation of this fact, however, and the reason why it does not harden when we consider its mechanical properties as compared with steel.

Iron is much more ductile than steel, iron can be twisted and bent in a variety of forms and steel cannot; this just means that the molecules flow with greater freedom and rapidity in the case of iron than in that of steel. So much more rapid is the molecular flow in iron as compared with steel that the molecules can nearly get back to their original position in *spite of the rapid cooling*. In fact, the amount of this decrease in specific gravity, when a metal or other substance is rapidly cooled, might be a measure of the rapidity of the molecular flow, or what is the same thing, the ductility of the metal.

There are two notable instances of this in the cases of copper and glass. In the case of copper, which is very ductile, the loss of specific gravity is exceedingly small, and in the case of glass so slow is the molecular flow that it flies to pieces when quenched, and it is only when treated in a very special manner that it can be hardened at all, *i.e.*, in the case of toughened glass, and the molecular tension is proved from its appearance with polarized light.

Altogether the relationship between ductility, decrease of specific gravity when quenched or suddenly cooled, and hardening power would be an exceedingly interesting study, and almost tempts me to make this letter even longer than it is.

ON FRICTION AT HIGH VELOCITIES.

REPORT OF THE COMMITTEE OF THE INSTITUTION OF MECHANICAL ENGINEERS.

From "Engineering."

THE subject with which this Committee has to deal has been defined as "friction at high velocities, specially with reference to friction of bearings and pivots, friction of brakes," &c. As the essential question involved in this is the influence of velocity upon frictional resistance, it has appeared neither necessary nor advisable that the reporter should give any special account of what has been written upon the subject of friction generally. Unfortunately, however, the results of his examination of the numerous works and papers bearing upon the subject to which he has had access have been chiefly negative, so far as relates to the particular question in hand. Very little work appears to have been done in connection with this question; and even of what has been done much seems inapplicable—on account of difference of conditions—to the ordinary work of the mechanical engineer.

A difference has long been recognized between what has been called static friction, or the friction of rest, and dynamic friction, or the friction of motion, the coefficient in the former case being in many instances much higher than in the latter. The recent experiments of Professor Fleeming Jenkin in connection with this matter, although made at the opposite end of the scale of velocities to that about which the Committee is now chiefly concerned, have great interest in connection with the general question of velocity and friction. By experimenting at extremely low velocities, he has shown* that in certain cases, where there is a very marked dif-

* Royal Society. Proceedings, 1877, p. 93.

ference between the two coefficients mentioned, the coefficient of friction decreases gradually as the velocity increases, between speeds of 0.012 ft. and 0.6 ft. (0.0036 and 0.183) meter per minute; and his experiments indicate a probability of a continuous rather than a sudden change in the value of the coefficient between the conditions of rest and motion. In cases where there is little or no difference between the coefficient of rest and motion, no difference was found at the velocities between which he experimented. His experiments were made with a very small steel spindle of 0.1 inch ($2\frac{1}{2}$ millimeters) diameter only, resting in rectangular V notches, the pressure being constant, and due to the weight (86 lbs. = 39 kg.) of a disc carried by the spindle, and revolving with it.

Professor A. S. Kimball has made a number of experiments* upon the question of velocity and friction. At common, but somewhat slow speeds, he finds the friction between pieces of pine-wood to decrease rapidly as the speed increases. With a wrought-iron shaft of 1 inch (25 millimeters) diameter, working in a cast-iron bearing, well oiled, an increase of velocity of rubbing from 6 ft. to 110 ft. (1.8 to 33.5 meters) per minute caused the coefficient of friction to fall to 0.3 of its first value. The pressure in this case was about 67 lbs. per square inch. (4.7 kg. per square centimeter). Other experiments on lubricated journals at smaller pressures gave a diminution of the coefficient from 0.15 to 0.05, as the velocities increased from 1 ft. to 100 ft. (0.3 to 30 meters) per minute. At such slow speeds as from 0.59 ft. to 2.2 ft. (0.18 to 0.67 meters) per minute a similar decrease was found; while at the still lower velocities of from 0.002 ft. to 0.01 ft. (0.0006 to 0.003 meters) per minute the friction increased with the velocity.

Professor R. H. Thurston has carried out a number of experiments to determine the effect of changes, not only in velocity but also in pressure and in temperature, upon the frictional resistance in lubricated bearings.† His conclusions are that the coefficient at first decreases, but after a certain point increases with the velocity, the point of change varying with the pressure and the temperature. At a pressure, for instance, of 100 lbs. per square inch (7 kg. per square centimeter) and a temperature of 150 deg. F. (65 deg. C.), the minimum value of the coefficient is reached at a speed lying between 100 ft. and 250 ft. (30 and 75 meters) per minute; while at the same pressure, but at a much lower temperature (apparently), the value of the coefficient increases continuously from 30 ft. (9 meters) per minute, the lowest velocity tried, up to 1200 ft. (360 meters) per minute. As the general result of his work Professor Thurston has come to the conclusion that for a cool and well lubricated bearing the coefficient of friction increases with the velocity, and approximately as its fifth root, at all speeds exceeding 100 ft. (30 meters) per minute. It is much to be regretted that Professor Thurston has published no information about his very important experiments in this part of the subject, except a few tables of epitomized results. Neither the sizes of the journals tested, the number of tests made, nor any particulars as to the variation of the experiments among themselves are given, and very few details as to the way in which they were carried out. Until this information is made accessible (as it is to be hoped it will be made) it is not easy to estimate the degree of importance to be attached to these results.

The well-known experiments of Poirée and Bochet* show that between velocities of 900 ft. and 3600 ft. (270 and 1080 meters) per minute the coefficient of friction both of wheels and of shoe brakes skidding on rails diminished very much—approximately (in the former case) from 0.2 to 0.13. The surfaces were of course quite unlubricated.

The recent experiments of Captain Douglas Galton and Mr. Westinghouse, described by Captain Galton in his papers read before the Institution,† afford very valuable information as to the effect of change of velocity upon the frictional resistances between brake-blocks and wheels, and also as to the simultaneous variation of the coefficient

* *American Journal of Science*, 1876 and 1878; also Thurston's "Friction and Lubrication," p. 182, *et seq.*

† "Friction and Lubrication," page 185. American Association for Advancement of Science, August, 1878, page 61.

* Mem. de la Soc. des. Ing. Civ. 1852, page 110, &c.

† See Proceedings Inst. M.E., June and October, 1878, and April, 1879.

of friction with the intensity of pressure, or pressure per unit of area. These experiments throughout showed a very remarkable diminution of the coefficient of friction with increase of speed over the very large range of from 400 ft. to 5300 ft. (120 to 1600 meters) per minute. The nature of the appliances used, however, permitted observations to be made only for about 30 seconds consecutively; and it was found that during this time the coefficient of friction always diminished rapidly. This decrease must of course cease after some time—apparently after a very short time—and the question arises, as was suggested by the reporter in the discussion on one of Captain Galton's papers, whether the difference between the frictional resistances at different speeds would still remain when these resistances had taken up their lowest values, or would then have disappeared. So far as can be judged from plotting out Captain Galton's results* the difference would remain. From working out a number of these brake experiments, the reporter found that the coefficient of friction was sensibly less at higher than at lower pressures, and that the coefficient of friction between the wheel and the rails (where the intensity of pressure might easily be seventy or eighty times as great as on the brake-blocks) was less than a third of that between the wheels and the brakes. From Professor Thurston's experiments with journals there appears the notable result that, while this is substantially corroborated for ordinary velocities and loads, there comes always a point (varying irregularly in the different cases and with different lubricants), after which increase of pressure increases the coefficient of friction, this change being more marked in the case of the lower velocities. The particular point at which this change occurs seems also to be partly dependent on the temperature. Within ordinary limits Professor Thurston takes the friction to vary (*cæteris paribus*) inversely as the square root of the pressure per unit of area; but this conclusion is very far from representing the average results of those sets of experiments which he has selected for publication.

* Proceedings Inst. M.E., April, 1879, Plate 23, Fig. 14.

No very large number of answers have been received to the inquiries sent out upon this subject. Of those which have come in, the most interesting are (1) a letter from Mr. Pearce, of Cyfarthfa, and (2) a letter from General Morin. The former gives particulars of indicator tests of a rolling-mill engine running empty at different speeds, from which it appears that proportionately a much smaller power was required to drive the engine at a high than at a low speed. The experiments are not of such a nature as to allow any general conclusions to be drawn from them; but they have considerable intrinsic interest, as relating to a form of experiment easily made, and the results of which, noted in a sufficient variety of cases, would afford really valuable information. General Morin's letter is specially interesting, as coming from such a veteran worker in the subject of friction as its writer. He disclaims altogether any notion that from his original experiments laws of friction could be laid down for conditions outside those under which he worked; and sees no reason to doubt that under such high velocities as often occur in practice the coefficient of friction may be considerably reduced. He thinks that an apparatus somewhat similar to that which he used, but modified in detail, would probably be the most convenient for carrying out further experiments. General Morin's letter is appended to this report.

The chief experiments made directly in connection with the subject under the consideration of the Committee have now been cited. From them it may be taken as established that, even at quite ordinary speeds, the value of the co-efficient of friction between different varieties of iron or steel is sensibly changed by changes in the velocity of rubbing. For dry rubbing surfaces, there can be little doubt that this change is a continuous decrease as the velocity increases up to the limits of the experiments made; for lubricated surfaces, of the form of ordinary bearings (having, however, pressure on both sides of the journal), Thurston's experiments point to the conclusion that at some point the coefficient ceases to decrease with increasing velocity, and begins to increase again. This conclusion can hardly be accepted as final without confirmation.

It has as yet been found only by one experimenter, and his results are in many points anything but regular. But at the same time no other experiments have apparently been made with lubricated bearings at anything like the speed (1200 ft. or 360 meters per minute) up to which he has worked.

Besides the general conclusions that the coefficient of friction is greatly affected by the velocity of rubbing, the existing experiments also show that it is greatly affected by the intensity of bearing pressure; and they raise some probability that the effect of altering the pressure is different at different speeds. It will hardly be possible therefore, in carrying out any experiments which may be thought advisable upon this subject, to dissociate the question of varying pressure from that of varying velocity. In working with lubricants it is also clear that the temperature very much affects the coefficient of friction; but there is very little evidence as to the effect of ordinary changes of temperature upon dry bearings.

TRANSLATION OF A LETTER FROM GENERAL A. MORIN.

"The results furnished by my experiments as to the relations between pressure, surface, and speed, on the one hand, and sliding friction on the other, have always been regarded by myself, not as mathematical laws, but as close approximations to the truth within the limits of the data of the experiments themselves. The same holds, in my opinion, for many other laws of practical mechanics, such as those of rolling resistance, fluid resistance, &c.

"It has therefore been no surprise to me that, in experiments on the resistance to the sliding of skidded railway wheels over rails, this resistance has appeared to diminish at higher speeds. The vibrations and strains produced in such cases would moreover occasion disturbances such as would wholly change the results.

"For journals revolving in stationary bearings, it is natural that, as the efficiency of the lubrication is affected by the speed, the friction should be so also.

"In the case therefore of loads, surfaces, or speeds, which largely exceed the limits of those that have formed the subject of my own investigations, I agree with the Institution of Mechanical Engineers that it would be well for further experiments to be tried.

"But after mature consideration I am of opinion that the question might be solved by an apparatus of a kind similar to the one I made use of, as described in the paper published in 1838 by the Academy of Science; provided that the new experiments were tried on a larger scale in regard to weight, diameter, and speed.

"In the apparatus referred to, the rotary dynamometer, which was the first of its kind, was mounted direct on the axle that was being experimented upon. It would be better that it should be separate from it, and that the axle should be driven by a belt.

"The kind of rotary dynamometer that I have subsequently employed, of which there are several models in the Conservatoire, is very convenient for these experiments, and can be used for high speeds. It would afford greater facility for applying sufficiently heavy loads.

"The diameter of the bearings should be much greater than is required for strength, in order that a sufficiently high surface velocity may be obtained with a moderate speed of revolution.

"For experiments made without any lubrication, anomalous results arising from wear produced by long-continued friction of the same surfaces might be avoided, if, instead of fixed bearings, an annular bush surrounding the journal were employed, which by some easily contrived arrangement might be shifted circumferentially at pleasure, either with a continuous movement or at intervals.

"The above are the suggestions that at present occur to me to offer in regard to arranging further experiments on the friction of axles in their bearings.

"If any scheme for an experimental apparatus in accordance with these ideas be submitted to me by the Institution, I shall have much pleasure in examining it and giving my opinion upon the arrangements proposed."

ON THE DECOMPOSITION OF SOME EXPLOSIVES.

From the "English Mechanic."

A SERIES of researches have been recently undertaken by MM. Sarran and Vieille, with a view to fixing the conditions of use of gun-cotton in mines. Through the important improvements introduced by Professor Abel into the manufacture of gun-cotton, this explosive is now prepared in homogeneous masses of determinate form and density, and can be kept without danger in the moist state. Its explosive force, comparable to that of dynamite, is greatly superior to that of powder, hence its use in mines offers great advantages. One inconvenience, however, connected with it is the production, on explosion, of noxious gases, which inconvenience the workmen. Its decomposition, in fact, produces carbonic oxide. This may be obviated by adding to gun-cotton an oxidant, such as a nitrate.

In a first communication to the Paris Academy, MM. Sarran and Vieille study comparatively the products formed, the heat liberated, the pressure developed by explosion in a closed vessel (1), of pure gun-cotton (2), of a mixture by equal parts of gun-cotton and nitrate of potash (3), of a mixture of 40 parts of gun-cotton to 60 parts of nitrate of ammonia (4), of nitro-glycerine, and (5) of ordinary blasting-powder.

We here give the results as to qualitative and quantitative composition of the gases furnished by each explosive under the normal conditions of its use. The table shows, in litres, the volume of each of the gases per kilogramme of the substance under such conditions.

Designation of substance.	CO	CO_2	H	N	O	C_2H_4	HS	Total vol. lit
Fine gun-cotton	234	234	166	107	..	..	..	741
Gun-cotton and nitrate of potash.....	"	171	"	109	45	..	..	325
Gun-cotton and nitrate of ammonia.....	"	184	"	211	6	..	..	401
Nitro-glycerine.	"	295	"	147	25	..	..	467
Ordinary blasting powder..	64	150	4	65	..	4	17	304

In a second note, the authors present the results, very different, obtained in decomposition of the same explosives, under a pressure near atmospheric pressure. These results have a theoretic interest, because they offer a remarkable example of the influence which the exterior conditions of reaction exert on the nature of the products.

From the practical point of view they give information as to the nature of the gases which may be expanded in mines in the cases of failure of detonation. Indeed, in most of those cases, the explosive, simply inflamed by the priming, fuses slowly under weak pressures. The authors have verified by a direct experiment, that the mode of the decomposition which is then produced in a little resistant-medium is quite assimilable to that which they realized in their apparatus.

As formerly they completed the volumetric analysis of the gases by absolute measurement of the volume occupied at temperature 0°, and at normal pressure, by the gases of a determined weight of the substance. The following table indicates (in litres) the volume of each of the gases per kilogramme of the explosive:

Designation of substance.	NO_2	CO	CO_2	H	N	C_2H_4	Total vol. lit
Pure gun-cotton...	139	237	104	45	33	7	565
Gun-cotton and nitrate of potash..	71	58	57	3	7	..	196
Gun-cotton and nitrate of ammonia	129	65	103	12	112	..	414
Nitro-glycerine....	218	162	58	7	6	6	452

It will be seen that, in this mode of decomposition, all the explosives liberate binoxide of nitrogen and carbonic oxide. It is important, then, in mining operations, to avoid failure of detonation by taking great care in arrangement of the priming.

RIVER CONSERVANCY, ILLUSTRATED BY DRAINAGE ADMINISTRATION IN HOLLAND.

By J. CLARKE HAWKSHAW, Member Inst. C. E.

From the "Journal of the Society of Arts."

THE word "Conservancy." when applied to rivers in this country, has generally hitherto been held to mean the keeping of them in a fit state for navigation. When our rivers were more used as highways, most of them had Conservancy Boards for navigation purposes. As long as such bodies prospered, our rivers were kept in far better order than they now are, not only for navigation but for other purposes. Some of these Boards have disappeared, some remain, and still retain their powers, but many are unable, for want of funds, properly to do their duties.

For this reason, and from the growth and spread of population along the river banks, new forms of conservancy have become necessary. Pollution by town refuse led to the passing of the Rivers Pollution Prevention Act, in 1876. The greater frequency of floods during late years has made it plain that conservancy for their prevention is necessary, and has given rise to the Rivers Conservancy Bill of this Session in Parliament.

Land Drainage Boards we have in plenty; each one does something, often little enough to ward off floods in its own district. But their sphere is too limited, they rarely look beyond their own narrow banks, and they will not work together. What we want to find out is, how to control and direct their work, so that, when possible, it may be made to benefit all, and also to aid it by works which no one of them could undertake.

Some advance has already been made towards the same end in other countries, and we may help ourselves in our difficulty by seeing how it has been met elsewhere.

Of all neighboring countries, Holland has the most artificial system of drainage. The very existence of the country depends on the water in and about it being kept under proper control by artificial means, and this has been the case from very early times. We might, therefore, reasonably suppose that the necessity for laws to control and provide for the management of rivers and water channels would soon have been felt in Holland, and such we find to have been the case.

Unions for drainage purposes of all lands, high and low, have existed in Holland for several centuries. Such unions are called "Waterschappen," and their oldest charters date from the 13th and 14th centuries.

In early times, the Boards of the Waterschappen were composed of the already existing corporations, and the government of the day named persons, called "Heemraden," to control and superintend the land drainage works which the corporations carried out.

Under these corporations no great progress was made until the 15th century. As the importance of the works which were undertaken increased at that time, so also the necessity then arose for a more complete organization to supervise and control them, and more important administrative unions, called "Hoogheemraadschappen," were accordingly instituted on a basis which has remained practically unchanged to the present day. A Hoogheemraadschap is a Waterschap, whose Board is composed of a "Dykgraaf," or president, and "Heemraden," or directors, with power to execute and maintain all the drainage works in which the inhabitants of their district have a common interest, with power to control all the minor works carried out by the small drainage corporations, or "Polders," and to enforce obedience on the part of private landowners and Polders to such laws as they may from time to time make.

The following powers are possessed by all the Waterschappen:

1. In cases of emergency, when floods are imminent, they may execute works,

or remove existing works, at the expense of those who should execute or remove them, but who fail to do so.

2. They may appropriate any materials which may be of use in repelling floods. The compensation to the owners to be settled afterwards.

3. They may take the earth required to make new or restore old embankments. The compensation to the owners to be settled afterwards.

4. They may levy rates to defray their expenses.

They may, moreover, by a law of 12th July, 1855, inflict a fine, not to exceed 25 florins, or imprisonment for from one to three days, for infringement of their regulations. The intervention of a judge is required, however, to legalize these punishments. They may also shut up or put out of use all the watermills, sluices, or other works by which interference with their regulations has been brought about, and this may be done at the expense of the offending owners. The Hoogheemraadschap of Rhineland is one of the most important of the large drainage districts in Holland, and I will describe its constitution in somewhat more detail, from information kindly furnished by its president, Mr. J. S. Clercq, and by Mr. J. Waldorp, the eminent Dutch engineer.

Its first charters were granted by William II., Count of Holland, in 1255, and by Count Floris V., in 1285. It extends from Amsterdam to Gouda, over an area of 262,685 acres (106,282 hectares). It is bounded on the north by the margin of the recently reclaimed Lake Y, on the west by the North Sea, and on the south and east by the Hoogheemraadschaps of Delfland and Amstelland. There is an adjoining district of Woerden, 41,992 acres (16,990 hectares) in extent, which pays a fixed contribution for certain sluicing privileges, but which forms by itself a separate Waterschap.

The administration of Rhineland consists of a combined board, composed of 16 chief or principal landowners, six members, called Hoogheemraaden, and a president, called Dykgraaf. The Dykgraaf and six Hoogheemraaden form an executive board, over which the Dykgraaf also presides, and which is assisted by a secretary, a receiver, and a civil engineer,

Besides the 16 chief landowners, there are 16 chief landowners assistant. The two together form an electoral body of 32 number, which meets once a year, to select three persons, either for Hoogheemraden or Dykgraaf. This list is submitted to the king, who chooses one of those named in it to fill the office.

No one under 23 years of age can be a member of the Board, or a member of the electoral body, and in order to be elegible for the office of Dykgraaf or Hoogheemrad, the person must be the owner of at least 62 acres (25 hectares) of land in Rhineland, and chief landowners and chief landowners assistant must own at least 50 acres (20 hectares). Relations nearer than the second degree cannot serve together.

Rhineland is divided into 16 electoral districts, each of which elects one chief landowner and one chief landowner's assistant. All persons, companies, and corporations paying yearly taxes for not less than $2\frac{1}{2}$ acres (1 hectare) have a right to vote. The payment of taxes on $2\frac{1}{2}$ to $12\frac{1}{2}$ acres (1 to 5 hectares) gives the right to one vote, and so on up to 200 acres (80 hectares) which gives the right to the maximum number of votes, which is ten. The vote may be given by written procuration.

All the members of the combined Board, including the Dykgraaf, and also the chief landowners' assistants who serve only on the electoral Board, are elected for six years, and a certain number retire each year.

The combined Board has charge of everything connected with the constitution of the district; it decides on the regulations to be enforced, and on the measures to be taken to enforce them; it decides on the execution and manner of carrying out all new and extraordinary works; it determines the right to pump or sluice on to the general bosom or upper catchwater; it buys, sells, and leases the property of the Hoogheemraadschap; it decides when action shall be taken in the courts against those who fail to comply with its regulations; lastly, it settles all disputes between the landowners or minor polder Boards. Against its decisions in such cases appeal may be made to the Deputy States

of the province; in the case of Rhineland to the Deputy States of North and South Holland.

The executive Board, consisting of the Dykgraaf and Hoogheemraden has charge of the execution of the resolutions of the combined Board. In cases of emergency, it may act independently, and at such times it may carry out any works it thinks necessary, may make banks, occupy land, and take any materials it may require from adjoining occupiers.

The executive Board may order the removal of any obstructions which interfere with the drainage of the district, or it may remove the same at the cost of the owners if they fail to do so; it regulates all deep excavations, whether for peat or other purposes; it sees that proper precautions are taken to prevent the sand of the sandhills from blowing away; it fixes the level at which the water has to be maintained in the different catchwaters or bosoms; it controls, in fact, all works affecting the drainage of the district.

The Executive Board publishes the regulations, and sees that they are enforced, and it keeps a correct register of all the taxable lands of the district.

The Dykgraaf is charged with the execution of all the resolutions of the Executive Board, and he has control over all the officials of the Hoogheemraadschap. In cases of immediate danger, he may act independently, with the full power of the Board.

The regulations prepared by the executive Board, after being open for public inspection, for 14 days, are submitted to the combined Board, who send them, with or without modification, to the Deputy States for approval. After being approved by the Deputy States, they are published, and eight days afterwards are in force.

The yearly budget which includes the salary of the Board and its officers, the expenses of the Board, the cost of maintenance of all ordinary and extraordinary works, and all other expenses, is prepared by the Executive Board, is settled by a general meeting, and has then to be approved by the Deputy States of the province. At the same time, the tax to be paid by the landowners is settled for the following year. The tax is fixed at an equal rate per hectare (with a few exceptions, resulting from old contracts, or for reasons which will be referred to later on) and is the same, whether the lands are high lands or low lands. Uncultivated sandhills, and the water area of the bosom, and bosom canals are free from taxes. The average yearly tax paid during the last 50 years in Rhineland, has been one shilling and fourpence per acre (two florins per hectare); the maximum tax in any year was two shillings, and the minimum eightpence per acre (three florins, and one florin per hectare).

The budget, after being open for public inspection for 14 days is printed and published, and the same course is pursued with regard to the amount of receipts and expenses for the past year.

All payments are made by the Receiver (Rentmeester) and the certificates are signed by the president and one member of the Executive Board. All other documents are signed by the president and secretary.

The taxes are paid in accordance with the register, which contains a correct description of all the properties in the district. This register is open for public inspection, during a fixed period.

If Rhineland neglects to execute necessary works, the Deputy States may order the execution of them, or may undertake them themselves, and charge the cost to Rhineland; the Deputy States may also propose to the King the dismissal of the Dykgraaf or Hoogheemrads, when they are either inefficient, or when they fail to carry out the requirements of the Deputy States. In all cases the King decides between the two. Any information which the Executive Board may require from the Polders Corporations in Rhineland, must be supplied by them, and they must submit to the Board their yearly budget, and an account of their administration. They may, however, appeal to the Deputy States against the Board's decisions.

In the years 1854–5, the Provincial States of North and South Holland settled general rules for the administration of the Polders Corporations, 230 in number, over which the Rhineland Board has general control. Each Polder has its own special rules.

Any resolution of the Hoogheemraadschap, or of the small administrations of

Rhineland, may be annulled by the Deputy States, if it is contrary to law, or if it is against the interest of Rhineland, or that of the province. The only appeal in such an event is to the king.

Such is the administration of the important district of Rhineland. Other districts throughout the country are governed in a similar manner.

It is generally thought in Holland, that the existing laws are all that is required to secure the good administration of the Waterschappen, and smaller drainage districts, or Polders, which they include. In confirmation of this opinion, I am told that disputes between the different interests in the large districts do not often happen, and the right of appeal to the Deputy States against the decisions of the different Boards is very seldom used. It is, however, thought that a law is required to regulate the relations of the large districts to one another, to the towns, and to the navigations. Yet, although the want of such a law has long been widely felt, the landed interest in the chambers, who are most interested in obtaining it, and who are, moreover, in a position to do so, have not yet ventured to move for it. The administration of the Waterschappen and Polders is so good, and all interests within them are now so well protected, that there is great reluctance to take any steps which may tend to disturb or lessen the authority of the existing Boards.

In a flat country like Holland, well defined natural drainage districts do not exist. When drainage districts are not divided by natural boundaries, the interests of those which adjoin must often be opposed, owing to their making use of common channels for the discharge of land water, or from other causes; and hence arises the necessity for a law to regulate their mutual relations. In this country, no such necessity need arise, if the boundaries of the combined drainage districts are made to coincide with the natural boundaries of the river basins, which are well defined, except in limited areas, such as are met with in the few districts of the Eastern Counties, where flat, alluvial tracts stretch across the lower courses of two or more rivers.

The whole of each natural drainage district should be under one Conservancy Board; above all, it is important that the outlet, by which the waters of the district are discharged into the sea, should be under the same control as the rest of the district. On many rivers, it will be found that the cost of the works inland will depend, to a great extent, on what can be done to improve the outlets to the sea, and, if these outlets are not, in some measure, under the control of the Conservancy Board for the river, their difficulties and expenditure may be very much increased.

If Conservancy Boards are formed for drainage purposes with only partial jurisdiction over a river, they will always be able to drain their land, though, perhaps, at a greater cost, without the co-operation of those situated lower down on the course of the river. But those so placed lower down will not save their pockets by not forming part of the same conservancy district, for unless they make provision for the more rapid discharge and greater volume of flood water, which will result from the works carried out above, they must suffer, more or less. This has happened in many places already, when works have been carried out by landowners on river banks without the co-operation of, and without regard to the interests of those lower down; and the same thing may happen if the drainage area near the river mouth is not under the same control as the rest of the river basin. Many of our ports are liable to be inundated by high tides, landwater floods, and combinations of the two. If the flood waters are passed to the sea more rapidly by improvements, this liability may be increased. It is therefore most desirable that no part of each natural drainage area should be left out of the union for conservancy purposes, least of all the lower parts adjoining the sea. If all are included, the interests of all can be watched and considered, and the best results may be obtained at the least cost.

In Rhineland, all lands, high and low, are obliged to contribute, in proportion to their acreage, to the general rate raised for the purposes of the Waterschap. Generally, the amount of the rate is the same, per hectare, for all. Exceptions are occasionally made in favor of some lands—when it can be proved that no benefit whatever can be derived

by them from the works for which the rate is raised. In such cases the tax is not wholly remitted; the lands are taxed at a lower rate. The principle that all lands, high and low, should contribute, is, I think, fair and right, but it may appear unjust that the rate should ever be of the same amount for the two descriptions of land. It must, however, be borne in mind that in Holland lowlands bear a very much larger proportion to the total land than in this country.

For example, the total area which drains into the general bosom of Rhineland is 302,600 acres (122,450 hectares). Of this, 26,740 acres (10,821 hectares) only, that is, less than one-eleventh of the whole consists of high land. This lies wholly within the district of the sandhills along the coast.

Of the remaining area 35,689 acres (14,442 hectares) are bosom lands. These are also held to be highlands in Holland, but they would not be called so in this country, as their average level is ten inches (.25 metres) below the mean level of the sea. The polders or lowlands in Rhineland lying from $3\frac{1}{4}$ to 5 feet (1 to 4 metres) below mean sea level, are 231,170 acres (93,546 hectares) in extent, and, lastly, the area of the bosom canals and lakes is about 9,000 acres (3641 hectares).

The bosom lands serve a special purpose in Holland. The water is pumped from the polders or lowlands into the bosom canals which run through the bosom lands, and it passes by them through sluices to the rivers or the sea. The bosom lands are liable to be flooded at times, indeed they form an additional reservoir space, to supplement that afforded by the bosom canals and lakes. The bosom lands, together with the bosom canals and lakes, form the general bosom of a district. Flooding of any part of the Polders is of the rarest occurrence. The pumps on which they are dependent are never stopped until the water rises to such a height on the bosom lands as to endanger the banks which divide them from the Polders. If the banks were to give way, all the water stored on the bosom lands would inundate the Polders. Rather than risk such a serious flood, the pumps would be stopped, and the rainfall would be allowed to accumulate on the lowlands for a time.

In the Fen districts of this country much of the land, corresponding to the bosom land of Holland, has been separated from the general bosom, and the receptacle for flood water has been thereby diminished. Such misappropriations are still going on, and, though a few landowners gain for a time by them, they, as well as their low-lying neighbors, must suffer in the end. The so-called dales along the River Witham were bosom lands; they now form part of the Fens, though the old banks which separated the two in former times still remain in places. In Holland, no such conversion of the bosom land into Polder land would have been permitted. That the area now left for bosom water is wholly insufficient in the Witham district, was shown by the disastrous floods which happened in 1877. In this country there is no Board, as in Holland, with power to say when it is no longer safe to pump water from the fens on to the bosom. Each fen continues to pump, quite regardless of the height of the bosom water, which may often be running back over the banks to its own pumps. The banks must give way sooner or later, but each fen hopes that its own bank may not be the first to fail. The failure of a bank may cause one or more fens to be submerged to a depth of five or six feet, whereas a few hours' cessation of the pumping throughout the district, might often prevent such a disaster. In Rhineland, by stopping the pumps which drain the Polders, a serious flood may always be prevented; but it would not always be so in this country, for we have to contend with an immense volume of highland water, which is not the case in Rhineland.

It is now an accepted fact that the water from much of the highlands is discharged more rapidly into the rivers than it used to be. An owner of the high land may say, "I bought my land subject to no charge for a river conservancy rate;" but with equal truth the owner of low land may reply, that when he bought his land it was not liable to be overflowed by the large volume of water which the owners of the high lands now pour into the river by their improved system of drainage. But

apart from such arguments, which are only of partial application, the principle that all lands should pay to maintain the main channels which, directly or indirectly, drain them is surely a fair one. If the incidence of rates is only to be determined by the benefits received, very many could not be justified.

No doubt the lowlands will benefit most, as now they suffer most, and they should bear the largest burden of the cost, the more so as they have to some extent rendered themselves more liable to be flooded, and have in many cases made the works which will be required to prevent floods more difficult to design, and more costly to execute.

In the first instance, costly works will often be required; works designed only to meet local requirements will have to be done over again, or be done away with altogether; obstructions will have to be removed which have grown up in the river channels, from natural causes, during years of neglect, or which may have been placed there to benefit individuals.

But even for such works no such rate need be feared as the land in Holland is subject to. Holland has to provide an artificial drainage for nearly all the land; we have, in most cases, only to provide that a good natural drainage system is kept in order, for, fortunately, the land in this country, which is without a good natural drainage, is very small in extent, when compared with the whole area.

To make a satisfactory law which shall provide for the government by one body of such large districts as are drained by our rivers, is a task of extreme difficulty To put it in practice will be more difficult. The interests which have to be dealt with are so many and so great that it will be impossible to satisfy all. In Holland, where want of such a general law is more keenly felt than here, they have not ventured yet to prepare it. Still, they are far before us in river conservancy. They have large districts admirably administered, and under the charge of able drainage engineers, and they, moreover, have recognized the principle that all land should contribute to maintain the channels which convey the water flowing from it into the sea.

THE PRESERVATION OF IRON FROM OXIDATION.

From "Iron."

It is now about three years since Professor Barff announced to the world his happy idea of applying in practice the well-known principle of exposing heated iron to the action of superheated steam, whereby it acquires a tenaciously adherent coating of magnetic oxide, which acts as a preservative of the metal against rust. We have now to announce the practical perfecting of another process for producing the same results which has been developed by Mr. George Bower, of St. Neots, Hunts. This consists in exposing heated iron to the action of air, and also of carbonic acid, whereby it not only acquires an equally efficient protective coating of the magnetic oxide, but at the same time assumes a delicate French-gray color, which for many purposes obviates the necessity for painting the metal. Before describing this process, it may prove interesting if we briefly glance at the history of its development. And first we may observe that it was only by the merest chance that Mr. Bower did not discover the very process which has added so much to the fame of Professor Barff. It appears that some twelve or fourteen years ago, Mr. Bower was making some experiments connected with the decomposition of water, by passing steam through red-hot iron in a retort, when he found that the iron decomposed the water rapidly at first, but that it gradually got less and less active, until it ceased to have any effect whatever. This led him to make an examination of the iron, when he found it coated with a sort of enamel, which suggested the idea of the process being used for that purpose. Upon exposing it to the atmosphere, however, the coating separated from the body of the iron, and Mr. Bower pursued the matter no farther. This separation was due, no doubt, to the iron operated upon being old and rusty. If it had been new the proba-

bility is that Mr. Bower and not Professor Barff would have been the first to introduce the coating of iron by magnetic oxide, produced by the action of aqueous vapor on red-hot iron.

When Professor Barff's success was published to the world it occurred to Mr. Bower that what the Professor was able to do with water he could do with air, and he began a series of experiments which, by dint of patience and perseverance, and the expenditure of a considerable amount of time and money, ended in complete success. The air-process, thus perfected by Mr. Bower, consists in the use of a retort or chamber, heated by the external application of heat. In this chamber the articles to be treated are placed, and when red hot, a few cubic feet of ordinary air are blown into the chamber, and the cover is tightly closed and left for a short time, when it is found that the iron has entered into combination with the oxygen in the air, and a first thin film of magnetic oxide has been formed. By repeating the operation as many times as may be necessary (and this depends on the nature of the articles operated upon) the desired thickness of the coating is produced. The time required for producing the protective coating varies from six to ten hours. Beautiful and simple as this operation is, it was found in practice that it was attended with considerable difficulty, and great wear and tear in heating the chamber and the articles in it by the external application of heat. It, however, occurred to Mr. Anthony S. Bower, a son of Mr. Bower, that it would be a great step in advance if the articles could be heated by the combustion of gaseous fuel inside the chamber, and if the coating of magnetic oxide could be produced at the same time. Thereupon commenced another long series of experiments, during which hundreds of tons of castings were treated and broken up as failures, but only to end, as in the purely air process, in complete success. Having recently been afforded the opportunity of investigating the working of this improved process at Mr. Bower's works, we are able to place all particulars before our readers.

In carrying out the process a set of three small gas furnaces for the production of carbonic oxide are constructed by the side of a chamber sufficiently capacious to contain about a ton of miscellaneous articles, and which, when we were examining the process, consisted of gas brackets and lantern frames, umbrella-stands, pots and pans, and ornamental figures and panels. Under this chamber is a series of pipes for heating the air, by the spare heat as it escapes from the furnace to the chimney, prior to its being used for the combustion of the carbonic oxide. This improved process, the joint patent of father and son, consists in alternately oxidizing and deoxidizing the iron. The articles are heated by burning the gaseous fuel inside the closed chamber, and heated air—in excess of the quantity necessary for the perfect combustion of the gas—is made to enter along with the fuel. This air together with the product of combustion (carbonic-acid gas) produces, next the metal, magnetic oxide, and on the top of it a film of sesquioxide, which is reduced to magnetic oxide by shutting off the air and applying carbonic oxide only, for a short time. But this is not all, for in addition to the protection from rust, the articles are rendered ornamental in appearance by the delicate French gray of the outer film of the coating they have received. If, however, the color should not be suitable from an artistic point of view, there is the certainty, that if it be necessary to paint over the coating, it will stand the same as if painted on wood or stone, as no rust can form underneath to throw the paint off, as is the case with paint upon ordinary iron. Another great feature of the process is, that it is an inexpensive one. The apparatus we saw at work at St. Neots is capable of dealing with a ton of ironwork per day, and the wages of one laborer and the cost of five or six cwts. of small coal is all the expense attending the operation.

Where there are foundries connected with blast-furnaces the process may be carried on at very little expense as pipes, and such-like goods could be oxidized by the hot-air blast, and, if necessary, be deoxidized by the furnace gas. Indeed, one of the best samples of iron Mr. Bower now has, is a bar which was subjected to the action of the hot blast by Messrs. Cochrane, of Dudley, so long ago as the middle of 1877, and it as perfect as ever, though it has been exposed out of doors ever since that time. In the Birmingham

and Wolverhampton districts there are thousands of tons of small castings produced daily to which the process could be applied. Indeed, the process opens out a new field altogether for the application of iron to the arts, and renders it capable of taking the place of some of the more expensive metals. The oxide thus formed has been tested very thoroughly, and is found to withstand all ordinary atmospheric conditions perfectly. It appears to be thoroughly incorporated with the metal, as, indeed, it must be, for it is the union of the iron with oxygen which forms the coating. A firm of iron-founders in Glasgow have successfully put the process to a severe proof both by fire and water, while Mr. F. J. Evans, the late engineer of the Chartered Gas Company, and Mr. Joseph Kincaid, C.E., both approve of the process after having tested for a lengthened period articles coated by it, and we can testify to its simplicity and the beautiful results obtained by it. We may also add that we have tested articles protected by this process by exposing them to the weather during the whole of last autumn and winter with the most satisfactory results. We certainly congratulate Mr. Bower and his son upon their double success in rendering cast and wrought iron not only useful but ornamental.

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers. The July No. of Transactions contains the following papers:

No. 196. The Hudson River Tunnel, by Arthur Spielman and Chas. B. Brush.
" 197. American Natural Cement, by F. O. Norton.
" 198. Notes on the South Pass Jetties, by Max E. Schmidt.

Wood Preservation.—To Engineers, Architects, Preservers of Wood, Chemists and others:—

The undersigned, a Committee of the American Society of Civil Engineers appointed to report upon the Preservation of Timber, earnestly solicit information concerning past experience in the impregnation and preservation of that material. Particulars of failures in this country, and if possible the reasons therefor are especially desired. Also, information on the following points, in each of the processes, which may have been used:

1. Kind of timber operated on—green or dry, age, dimensions, etc.
2. Preserving ingredients injected.
3. Quantity injected per cubic foot or tie.
4. Mode of application, process, time employed, degree of heat, pressure, vacuum, etc.
5. Subsequent use and exposure of timber, (bridges, buildings or track.)
6. Result of preparation and comparison with life of unprepared timber.

This special and any general information on the subject is respectfully solicited.

Replies can be mailed to the Chairman of the Committee, B. M. Harrod, *Chairman*,
122 Common st., New Orleans, La.
G. Bouscaren, 82 West 3d st., Cincinnati, O.
E. R. Andrews, 10 Warren st. New York City, N. Y.
E. W. Bowditch, 60 Devonshire st., Boston, Mass.
Col. Geo. H. Mendell, U. S. Engineers, San Francisco, Cal.
J. W. Putnam, P. O. Box 2734, New Orleans.
Committee.

Engineers' Club of Philadelphia.—No. 5 of the Proceedings which has just come to hand contains:—

No. XXI. Angular Pitch of Square-threaded Screws, by Wilfred Lewis.
No. XXII. Water Gas from Coal and Petroleum, by Gen. H. Haupt.
No. XXIII. The St. Gothard Railroad, by Chas. E. Billin.

IRON AND STEEL NOTES.

Northern crude iron trade.—The condition of the crude iron trade of the North cannot be considered an entirely satisfactory one; but the most remarkable feature about it is the extremely irregular state of prices, both of iron and of the raw materials. It is true that as contracts expire this is being remedied; but it is tolerably certain that at the present time there is such a variance in the prices that are being received by the makers for pig iron as is rarely known. Some contracts are now expiring for crude iron at 3*l.* per ton, or over 1*l* 3s. above the market rate, but they are accompanied by a very high cost of production in a few instances. The rapid fall in the price of pig iron and also in that of coke caused this irregularity, and as contracts are being renewed on a lower level it is being reduced, whilst the slight tendency of prices upward is also assisting in the renewal. But it cannot be denied that the fall in the demand for crude iron for the United States has already registered its full effect on the prices, though it is possible that it may be in the future known through diminished production also. As the price of pig iron advanced in the North of England under the influence of that inflation of demand known at the end of last year, there was a rapid rise both in prices and in the extent of the output of crude iron; and had it not been for the increased requirements of the local shipbuilding trades, the fall in prices within the last two months would have been before this followed by a decline in the extent of the production also. But the large demand for plates and angles has caused stocks of pig iron in the hands of makers to decline, and up to the present it may be said that there

is a demand up to the production, so that a restriction of the output from this cause is not yet probable. It may, however, follow from another cause.

A large number of the furnaces in the North of England, and especially in the Middlesbrough district, may make iron to profit even at the present low range of prices. Some of the owners of these own also the coal mines that supply fuel, iron mines, and limestone quarries for the flux, so that there is only the addition to cost of a percentage to the wages of the ironstone workmen and furnacemen, and of the addition to the cost of carriage made at the beginning of the present year. But many of the furnaces are not worked under these conditions. And where the owners do not own the contributory mines, and where the furnaces are situated at a distance from the latter, or from the sea coast, they cannot be expected to produce iron so cheaply as those more favorably situated. It is to be expected that if the present range of prices long prevail there will be a reduction in the output by the blowing out of some of the more isolated furnaces. If, however, a renewed demand for pig iron were to set in from the United States or from any other quarter, with the present balance between the demand and the supply, an increase in prices would be probable, which would force up prices till they were generally profitable. During the first five months of the present year, the total production of pig iron in the Cleveland and Durham district was in round numbers 1,000,000 tons—an unparalleled output—and as that was attained not only with no increase in the stocks, but with an extensive fall therein, it is certain that any present addition to the demand would force up prices. It is true that there is a reserve of productive facilities yet uncalled into action—to the extent of about forty blast furnaces in the whole of the northern district; but a large number of these furnaces are so placed that it is impossible to light them up early. Companies owning one-half of these furnaces are in liquidation, and their works could not be started for many months. With the low level of prices now attained, then, any fall in demand would be reflected by a declension in the output; and any increase in the demand would most probably be early followed by a rise in the prices. In this fact, then, there is the key to the future condition of the crude iron trade of Cleveland and Durham, if it be concurrently remembered that there is a larger production of hematite iron, and thus a larger consumption locally—a larger consumption, that is, in the locality of the quality of iron of all kinds produced in the district. It is very doubtful whether the tide will turn in the one direction or the other; but it seems to be most probable that there will now be an addition to the demand from the United States, though probably on a much more limited scale than that which has now been almost entirely gratified. It seems to be clear that English iron can, despite the heavy duty, be landed in the United States cheaper than the native metal can be produced; and whilst this is the case it is almost certain that there will be a continuance of shipments from this country When the great bulk of the iron that has recently been sent to America was contracted for, the prices here were at a very low ebb, and as prices rose new orders became less, though in fulfillment of these old orders there was an increasing shipment. Now that what may be considered the lowest range of prices are again reached, there are renewed inquiries from the United States both in Cleveland and in Scotland, and these are tolerably certain to result in new contracts. It may be taken, then, as the most probable future course of the trade, that a slow upward movement will set in. Slow, because the facilities of production in use in the North of England and in Scotland are very much greater now than they were when the demand previously set in; and this being so, and the supply having hitherto allowed of very large shipments to the United States, these large shipments may still be made without derangement of the balance between supply and demand that is supposed at the present to exist. Should this prove to be the case, the fall in the stocks that has been known in the Cleveland district during the greater part of the year may be expected to continue, and with that fall there would be the movement upwards in price which we have indicated as probable. A short time will show the movement of the tide, but its speed will not be so great as on the last setting in of the flow.

THE IRON PRODUCTION OF THE UNITED KINGDOM.—Mr. W. G. Fossick, of 86 Cannon street, has recently prepared and published, through Messrs. E. and F. N. Spon, of Charing Cross, a very complete and carefully compiled statistical diagram of the iron and steel trades of the United Kingdom from 1830 to 1880. This diagram shows, for the last fifty years, the total production of pig iron, the exports of iron and steel, and the stocks of pig iron in tons at the end of each year. It also includes, for the same periods, the prices of Scotch pig, Welsh bars, Staffordshire bars, and iron rails between 1864–1880, and steel rails from 1864 to the present time. Information is thus given at a glance, which it would be tedious to obtain from statistics, and in a manner to show strikingly the variations in the trades dealt with for half a century. As may be expected the gradations in production, though always increasing, show periods of deep depression. The following figures taken from this diagram are of interest:

Year.	Production of Pig Iron.	Price of Scotch Pig.	Price of Welsh Bars.	Price of Staffordshire Bars.
	tons.	s.	s.	s.
1830	678,417	102	110	117
1834	158,166	86	115	135
1840	1,396,400	77	135	158
1852	2,701,000	37	92.5	120
1853	1,261,272	65	190	220
1872	6,741,920	70	140	160
1879	6,200,000	40	93	150

The above are the lowest prices of the respective years, and in some cases were subject to remarkable fluctuation. Thus in 1872, when the lowest prices for Scotch pig and Welsh and

Staffordshire bars were respectively 70s., 140s., and 160s., they touched 130s., 290s, and 320s. respectively, to suffer, however, a very severe fall again before the close of the year. Steel rails were at their highest prices—17*l.* 10s.—in 1864 and 1872–73, to fall, however, in 1870 to 10*l.*, and last year to 4*l.* 10s. The year 1873 was another prosperous season for iron rails, which touched 12*l.* a ton, and last year was the worst, as they fell to nearly 80s. We strongly recommend this chart to every one interested in the British iron trade, and we may add that it is extremely well executed.

RAILWAY NOTES.

TRACTION ON TRAMWAYS.—The Paris Compagnie des Omnibus have been carrying out on one of their lines an interesting series of dynamometric experiments to determine the relative resistance of tramway vehicles and omnibuses running on the ordinary road. The line on which the experiments were made is that between the Eastern Railway Station and Montrouge, and the results have been lately communicated by M. Rousselle to the Société d'Encouragement pour l'Industrie Nationale. From M. Rousselle's paper we learn that the total length of the line between the terminus of the Eastern Railway and Montrouge in 3.95 miles, of which about 1.84 miles are fairly level. Leaving the Eastern Railway Station, there is first a sharp descent of 1 in 48 for about 480 yards, then a tolerably level length of about 1¼ miles, and then a steady rise to Montrouge, commencing with a steep gradient of 1 m. 35.7 for a distance of about 530 yards. From the top of this last-mentioned gradient the rise becomes gradually less severe for the last 530 yards or so before arriving at Montrouge, having a gradient of 1 in 666 only. The runs were made over the line in both directions, an extra horse being attached during the ascent of the steep gradient of 1 in 35.7 above mentioned, and the journey was made from the Eastern Railway Station to Montrouge in 51 minutes, while that in the reverse direction was made in 44 minutes. The speeds were the same for both omnibus and tramcar. The omnibus used weighed loaded 3 tons 12 cwt., and the tramcar 6 tons, while the dynamometer employed enabled a record to be obtained of the work done on each portion of the course. The general results were as follows: In the trial with the ordinary omnibus the work done by each horse on the journey from Montrouge to the Eastern Railway Station varied from 54,196 to 29,010 foot-pounds per minute, the mean for the whole trip being 36,892 foot-pounds per minute. On the reverse journey the work done per horse varied from 60,097 to 21,934 foot-pounds per minute, the mean effort for the run being 34,901 foot pounds per minute. The mean of means for the two journeys is thus 35,896 foot-pounds per minute exerted by each horse. In the case of the tramcar, on the other hand, the work done by each horse on the journey from Montrouge to the Eastern Railway Station varied from 36,403 to as little as 4392 foot-pounds per minute, the mean for the whole run being 23,834 foot-pounds per minute. On the reverse trip, on the other hand, the work done per horse varied 52,798 to 18,123 foot-pounds per minute, the mean for the journey being 32,348 foot-pounds. The mean of means for the tramcar is thus a power exerted of 28,091 foot-pounds per minute for each horse. This is consider, ably lower than in the case of the omnibus, but, on the other hand, as M. Rousselle points out the exertion in starting is far greater in the case of the tramcar than in that of the omnibus, and this involves increased fatigue for the horses. The pull exerted at starting was found to vary from 440 lbs. to 772 lb.s in the case of the omnibus, and from 617 lbs. to 1100 lbs. in the case of the tramcar. As for the resistance to traction per ton, it was found, taking the means of the journeys in the two directions (so as to eliminate the effects of gradients as far as possible) to average 42 lbs. per ton for the omnibus, and 20.1 lbs. per ton for the tramcar; the mean pull exerted by the horses thus being $42 \times 3.6 = 151.2$ lbs. in the case of the omnibus, and $20.1 \times 6 = 120.6$ lbs. in that of the tramcar.

HUGHES'S STEAM TRAMWAY LOCOMOTIVE.—Hughes's patent tramway locomotive, which has already been adopted in Glasgow, Wantage, Paris and Lille, made a trial journey through the streets of Birmingham, on Friday last, with the Mayor and several members of the Corporation. The locomotive resembles externally a small tramcar on a level. It draws three cars, each drawing forty persons, and is calculated to draw a car of forty passengers up a gradient of 1 in 13. It has 9-inch cylinders, 12-inch stroke, and 3-feet 6-inch cells, fitted with condensing apparatus, and runs five miles with one supply of water and coke. The trial was deemed satisfactory.

ENGINEERING STRUCTURES.

RECONSTRUCTION OF THE TAY BRIDGE. Readers of *The Engineer* are aware that by favor of Parliament the standing orders were suspended, so that a Bill has been introduced this session for the re-building of the Tay Bridge. Power is taken in the bill to raise £2 0,000 additional capital, either in the shape of ordinary or preference stock, with borrowing powers to an equal amount; and as the North British Company is at present losing much money in conducting its traffic without the bridge, the works will be entered upon and pushed forward with all possible expedition. The plans for the reconstruction of the bridge have been lodged in the Dundee Sheriff Court. When the bridge was originally constructed, after a public inquiry, it was stipulated that there should be a clear height below the central girders above high-water mark, so as to keep the water way clear for ships passing up the river to Perth. Such a requirement was considered by many unnecessary for all the traffic ever likely to find its way beneath the bridge, and the alteration in the mode of loading the central girders, which this stipulation rendered essential, appears to have been tacitly allowed to have had the effect of diminishing the stability of the structure at this point. It is therefore believed that no serious opposition

will be offered in parliament to the lowering of the height of the bridge, which is proposed to be done in the center from 88 feet to 57 feet. According to the plans, it is proposed to begin to lower the line on the Fife side, in the parish of Forgan, some distance before it reaches the structure, by a gently falling gradient, until it joins the south end of the bridge, when the height will be 57 feet. This height will be continued from the south end until the eighth fallen pier is reached, when the line will begin to fall gradually towards the north shore. For a considerable distance on the Fife side the line falls at a gradient of 1 in 300 until it reaches the bridge, when there is a slight rising inclination for 600 feet. From this point the line is almost level until the eighth fallen pier, where the fall in the line begins at 1 in 230, and gradually increases till, near the north of Dundee side, it is 1 in 74. The spans in the southernmost portion of the bridge still remaining are not to be altered in width, but the 13 wide spans of 245 feet, which were in the center of the bridge before the accident, are to be narrowed to about one-half the width by the introduction of additional piers. The first five 245-feet spans, counting from the south end of the fallen portion, are to be divided into ten spans of 109 feet each, and will stand at a height of 57 feet above high water of ordinary spring tides; between the fifth and sixth fallen piers there will be two spans of 100 feet wide and 57 feet in height; between the sixth and eighth fallen piers four spans of 109 feet wide and 57 feet high; between the eighth and ninth fallen piers two spans of 100 feet wide, gradually falling in height from 57 feet to 54 feet 9 inches; and from the ninth fallen pier to the first remaining pier on the north side there will be eight spans 109 feet wide, and falling in height from 54 feet 9 inches to 45 feet. The width of the other standing spans of the bridge is not to be altered, but their height will be modified to suit the falling gradient of the line; and the bowstring girder close to the Dundee shore will, in accordance with this provision, be reduced to 26 feet, and the smaller girder that spans the esplanade, before the station is reached will be lowered to about 18 feet. The line will be carried across the entire way on the top of the girders, so that the expedient resorted to by the engineer in the fallen portion of sending the train through the center of the girder will not be repeated. In the meantime it is not proposed to construct the bridge so as to admit of a double line of rails; but the new piers will be of such width that they will be able to carry a double line, should such a thing be resolved upon at a future time. Of course the plans are subject to such changes as may be required by the Board of trade. By a clause in the bill the Company ask for power to delay the traffic on the bridge, should that be deemed necessary, on account of the state of the weather.—*The Engineer.*

A *Times* correspondent at Bucharest writes that Sir Charles Hartley has been making his annual inspection of the Sulina and the works of the European Danube Commission. The works advocated in his report for this year comprise the cutting of a new entrance, 3000 feet long, into the Sulina branch from the main St. George Channel, in order to avoid several very ugly bends at the present entrance, which are not only very troublesome for long steamers as well as sailing vessels, but which are constantly growing more shallow from the sediment deposited on the dead angles of these bends; also the deepening of the mile reach of Gondarva, where there is only a depth of 13 feet at low water, whereas the average depth of the rest of the Sulina branch is over 15 feet at low water. To execute this latter work, Sir Charles advises the purchase of a new dredging machine at a cost of 370,000 francs. For the remaining two years of the duration of the Commission the eminent engineer advises the cutting of two other canals, each 3000 feet long, to get rid of two more very objectionable bends. The total expenditure of these improvements, including the cost of the dredge, is a little over 3,000,000 francs. When the above-mentioned improvements are completed, the Sulina branch will have a depth of 15 feet at low water, the objectionable bends will have been obviated, and the navigability of the channel reduced to a uniformity throughout its entire length, which cannot be improved without extensive works along nearly the whole of the distance, and costing a very large sum of money.

ORDNANCE AND NAVAL.

AN ENORMOUS STEAMER.—John Elder and Co., Glasgow, are to build for the Guion Line a steamer 500 feet long, 50 feet broad, and 40 feet deep; engines 10,000 horse-power; indicated and gross tonnage 6400.

LARGE ORDERS FOR TORPEDO BOATS.—Large orders for torpedo boats are now being executed by Messrs. Thorneycroft, of London. The firm has delivered eleven first-class and twelve second class torpedo boats. Four are now awaiting official trials, six are shortly expected at Portsmouth, and there are being built another first-class and twenty additional second-class boats. A first-class boat costs over £5000, and a second-class half that amount. Other torpedo boats are also being supplied by other firms.

THE "ALBERT VICTOR."—On the 3rd of July, this ship, taken by Mr. Samuda, her builder, and Messrs J. and W. Penn, the makers of her engines, from Gravesend to Folkstone, where she at once began her career as one of the South-Eastern Company's passenger boats across the Channel to Boulogne. The Albert Victor, steaming against a strong head wind took only three hours and 45 minutes on the run from Gravesend to Folkstone, a distance of 84 miles, her prodigious speed, steadiness, and freedom from vibration, exciting the special admiration of Mr. E. J. Reed, M. P., who, with Mr. Norwood, M. P., several directors and officials of the South-Eastern Railway, and a party of friends, had been invited to take part in the trip. At the luncheon, Mr. Samuda

stated that the Albert Victor, steel-built and with oscillating engines developing 2800 indicated horse-power, accomplished 18½ knots, and was about the fastest thing afloat. Mr. Penn also made some striking remarks about the engines, which were not compounded, and therefore not the most economical of coal, but which for driving power and results in speed put to the very best possible use the saving in weight and the improvement in her lines obtained by the use of steel in the fabric of the ship. This saving in the case of the Albert Victor is about 130 tons.

LAY TORPEDOES.—The manufacture of Lay torpedoes is being carried on with great energy in Russia, and several of these formidable weapons will, it is stated, be shortly completed and forwarded to the chief ports on the Baltic and Black Sea. The Lay, like the Whitehead, is a locomotive torpedo; but while the latter, after it is once launched, is no longer under control, the movements of the former can be guided and directed throughout its course. At the will of an operator on shore, or on board a ship if the torpedo is discharged from the latter, it can be made to turn to the right or left, to rise or sink in the water, to explode at any moment, or finally, should it fail to reach the object against which it is sent, it can be brought back again to the point from which it started. A few months ago some very successful experiments were carried out with Lay torpedoes in the Scheldt, near Antwerp, when one of them was sent against a boat anchored 3000 meters, or very nearly two miles from the operator on the bank of the river. To reach its mark the torpedo had in the first instance to move along a line of buoys at an oblique angle to the current, and had then to turn on to a course at right angles to the direction it had been previously taking; and this difficult feat it successfully accomplished. That a torpedo which can be thus kept under control up to the moment when it becomes desirable to explode it must prove extremely valuable for coast defence purposes is very obvious; and therefore it may be assumed that it will soon be adopted by other countries besides Russia.—*Iron.*

BOOK NOTICES.

PUBLICATIONS RECEIVED.

A MANUAL of the Alkali Trade, including the Manufacture of Sulphuric Acid, Sulphate of Soda and Bleaching Powder. With 232 illustrations and working drawings. By F. Lomas. Longmans, Green & Co. Price, $20.

Bulletin of the American Geographical Society No. 4. Printed for the Society.

Proceedings of the Institution of Civil Engineers:

"The Caledonian Railway Viaduct over the River Clyde at Glasgow." By Benjamin Hall Blyth, M. I. C. E. "The Purification of Gas." By Harry Edward Jones, M. I. C. E. "The Calder Viaduct." By David Monroe Westland, M. I. C. E. "Note on the San Francisco River; Brazil." By W. Milnor Roberts, M. I. C. E. "Cleopatra's Needle." By Benjamin Baker, M. I. C. E.

INSTRUCTIONS FOR TESTING TELEGRAPH LINES, AND THE TECHNICAL ARRANGEMENT OF OFFICES. By LOUIS SCHWENDLER. Vol. 2. London: Trübner & Co. For sale by D. Van Nostrand. Price, $4.00.

The present volume is especially intended to supply *testing information* to officers in charge of telegraph stations for whom the more complete testing apparatus is not available, but who have to perform their testing duties by aid of the tangent galvanometer described in the beginning of the present volume.

The present work bears no great likeness to other works on telegraphy, simply because its sole object was to introduce a general system of testing.

The Appendices treat more fully upon the theory of The Tangent Galvanometer—The Galvanic Element—Electric Resistance of the Earth, etc., etc.

QUALITATIVE CHEMICAL ANALYSIS. By SILAS H. DOUGLAS, M.A., M.D., AND ALBERT B. PRESCOTT, M.D., F.C.S. Third edition, wholly revised, with a study of oxidation and reduction. By OTIS COE JOHNSON, A.M. New York: D. Van Nostrand. Price, $3.50.

The present edition is one of the most complete of the many guides to practical chemistry. The reputation earned by the first edition has extended the use of the work among practical chemists and students throughout the country.

The additional matter which constitutes Part IV of this edition is presented, say the authors, "with much interest as to the reception which its distinctive method may obtain among chemists." This method consists in assigning a positive or negative character to the *bond*. Thus hydrogen in combination has always one bond, and it is always positive. Oxygen has two bonds always negative. The sum of the bonds of any compound are equal to zero.

Oxidizing agents are those that *increase* the number of bonds of some other substance. Reducing agents *diminish* them.

From these principles are derived rules for correctly writing chemical equations. Examples are also given for practice. The principle assumed seems worthy the serious consideration of teachers.

THE WAR-SHIPS AND NAVIES OF THE WORLD, Containing a Complete and Concise Description of the Construction, Motive Power, and Armaments of Modern War-ships of all the Navies of the World, Naval Artillery, Marine Engines, Boilers, Torpedoes, and Torpedo Boats, with 64 Full-page Illustrations. By CHIEF ENGINEER J. W. KING, U. S. NAVY. Boston: A. Williams & Co. Price, $7.00.

This work contains correct descriptions of all the modern war-ships built and building, with dimensions and particulars, and accompanied with effective drawings, showing the design, proportions, and plan of the ships, and the disposition of their batteries. An interesting comparison is made between the fighting powers of the British and French navies. The powers and dimensions of the great guns now in use or in process of manufacture are exhibited by drawings and descriptions. There

are additional chapters upon marine engines and boilers, torpedoes, and the methods of torpedo warfare, with drawings and descriptions of the latest torpedo boats.

The writer has enjoyed exceptional facilities for obtaining the information contained in the book, by personal inspection in most cases, supplemented by friendly relations and correspondence with constructors, manufacturers, and others.

The work is one that should find a place in public and social libraries, in clubs, in government offices, and one which no naval officer, desiring to be informed of the effective force of the different navies of the world, and the great changes which are being made in naval warfare, can afford to be without. It will be found useful and entertaining to the general reader also, and will be valuable as a reference book in the private library. It is especially designed to awaken the American public to a sense of the relative decline of our own navy, and inspire an enthusiastic interest in its restoration.

ARTIFICIAL MANURES; THEIR CHEMICAL SELECTION AND SCIENTIFIC APPLICATION TO AGRICULTURE. By M. GEORGES VILLE, translated and edited by WM. CROOKES, F. R. S. London: Longmans, Green & Co. For sale by D. Van Nostrand. Price, $7.50.

A book for the scientific agriculturist. The eminence of both author and English Editor is sufficient guaranty of soundness in the scientific principles. The whole is presented in a series of lectures, of which six relate to "Theory and Practice" and nine more to "Practice Extended by Theory." Separately they treat as follows:

I. Plants, their Composition, Growth, Nutrition and Cultivation—II. Assimilation of Carbon, Oxygen, Hydrogen and Nitrogen—III. Function of Mineral matter in Plant Production—IV. Typical Fertilizers—V. Comparative cost of Farmyard and Chemical Manure—VI. Waste Portion of Crops Important as Fertilizers—VII. Past and Present Systems of Agriculture—VIII. Plant Production—IX. Analysis of the Soil by the Plants themselves—X. Farming with Farm Manure only—XI. Formulæ for Manures—XII. Effects of Farmyard Compared with Chemical Manure—XIII. Live Stock—XIV. Live Stock—XV. Agricultural Industry.

The Apendix covers sixty pages and contains tables, analysis, and results of Experiments.

A PRACTICAL TREATISE ON HIGH-PRESSURE STEAM BOILERS. By WILLIAM M. BARR. Indianopolis: Yohn Brothers. Price, $4.

This book presents a record of the author's experiments, notes, memoranda and practice during several years. Much of the practical information has never before been published. The chapters treat separately of:

1. Introduction—II. Cast Iron as a Material for Boilers—III. Wrought Iron as a Material for Boilers—IV. Steel as a Material—V. Testing Wrought Iron or Steel for Boilers—VI. Riveted Joints—VII. Welding, Flanging and Influence of Temperature—VIII. Strength of boilers—IX. Heating Surface and Boiler Power—X. Externally Fired Boilers—XI. Internally Fired Boilers—XII. Boiler Setting—XIII. Feed Apparatus—XIV. Heaters and Economizers—XV. Safety Apparatus—XVI. Incrustation and Corrosion—XVII. Sectional Boilers. 204 cuts illustrate the text.

ELECTRIC LIGHT: Its Production and Use. By G. W. URQUHART, C. E. Edited by F. C. WEBB, M. I. C. E. London: Crosby Lockwood & Co. For sale by D. Van Nostrand Price $3.00.

The rapid development of the various metnods of producing electric illumination excites a general interest in the subject, and leads to demands for carefully-prepared works relating thereto. At the present time, as much sound knowledge is required to determine what among recently current literature to discard as what to accept as a part of the authentic history of the subject. The present work possesses the merit of a carefully-compiled account of the batteries, dynamo-machines, and lamps which have been brought forward as late as April of this year. The chapters treat separately of:

I. Introduction—II. Voltaic Batteries—III. Thermo-Electric Batteries—IV. Magneto-Electric Generators—V. Electro-Magnetic Machines—VI. Dynamo-Electric Machines—VII. General Observations on Machines—VIII. Electric Lamps and Candles—IX. Measurement of Electric Light—X. Mathematical and Experimental Treatment of the subject—XI. Application and Cost of the Electric Light—Tables Relating to the Several Machines.

Ninety-four well-executed cuts illustrate the text.

WOOD-WORKING MACHINERY: Its Rise, Progress and Construction. By M. POWIS BALE, C. E. London: Crosby Lockwood & Co. For sale by D. Van Nostrand. Price $5.00.

This work relates, as its title indicates, entirely to a single branch of practical technics.

The illustrations, which are numerous, are confined to the designs of English, French and American engineers.

MISCELLANEOUS.

HERR OBACH proved, a few years since, that alloys of the metals proper, such as lead and tin, potassium and sodium, and sodium amalgam, conduct a current without being decomposed. Herr Elsässer has recently (*Ann. der Phys.* No. 11), experimented with combinations of metals with the half-metallic elements, antimony and bismuth, passing a current through the fused alloy in a glass tube with electrodes of gas carbon. There was here also no decomposition. The author notes that the transition from these compound conductors, of the first class to the electrolytes, is no sudden one. Between the two groups are substances, which at a low temperature conduct without decomposition, but at a high one, and even partly before they melt, are electrolyzed, *e. g.* copper and silver sulphides, and the

sulphides of lead, nickel, iron, bismuth, tin and antimony. To this middle class, also, may be added a number of compounds, which have not hitherto been electrolyzed, probably because they are so difficult to fuse (such as the oxides of tin, iron and chromium); the electrolytes proper do not conduct without being electrolyzed; and to this class belong especially the haloid compounds of the metals, which are not decomposed in the solid state because they are insulators; whenever they begin to conduct, being fused, they are decomposed. Lastly there is a fourth class of compounds, which in general do not conduct, either with or without decomposition.

COST OF TUNNELING.—The cost of some of the chief tunnels completed since the commencement of the railway system is as follows:—

Name.	Place.	Material.	Cost p.yard run.
Limehouse.....	Footway underThames	London clay	£ 30
Lydgate.....	L.& N.-W. Ry.	Coal. meas.	30
Guildford.....	L. & S.-W. Ry.	Chalk	30
Salisbury.....	Ditto	Ditto	30
Petersfield.....	Ditto	Ditto	30
Netherton.....	Birm.Canal.	Marl	39.25
St. Catherine's....	L. & S.-W. Ry.	Sand	40
Honiton....	Ditto	Marl and green sand	50
Bletchingley	S.-E. Ry.	Clay	72
Buckhorn Westor.	Sal.& Yeo.Ry.	Clay	72
Chicago.....	U.S.A.	—	88
Batignolles.....	Paris	—	95
Box.....	Gt.West. Ry.	Oolite & marl	100
Saltwood.....	S.-E. Ry.	Sand	118
St. Gothard.....	—	—	122.7
Kilsby	L.& N.-W. Ry.	—	145
Thames.....	—	Clay and silt.	1299

Builder.

BONSILATE.—One of Newark's (N. J.) latest industries is the establishment of a company engaged in the manufacture of a new product intended to substitute ivory, hard rubber and kindred substances employed in the manufacture of a variety of useful or decorative articles. The material is said to be composed chiefly of finely ground bone, which is agglutinated by the addition of some cementing compound. From the peculiarity of the name, we should suspect this to be silicate of soda, though our account states that it is at present the secret of the manufacturers. The name of J. W. Hyatt, which is mentioned as one of the inventors of "bonsilate," will be recognized as that of one of the inventors of the singular composition known as "celluloid,"

The manufacture of this new product is said to have progressed so far that already a large variety of articles are made of it and placed upon the market. The material can be molded in dies like any other plastic composition. It can be formed into slabs, bars or sheets, which can be turned, polished, or sawed into desired shapes; and by the addition to it of various coloring pigments, a variety of costly and decorative substances, such as coral, jet, malachite, colored marbles and other stones, can be closely imitated with it.

From the account given, it must, like celluloid, possess a high degree of elasticity, as one of the leading companies of this city is reported to be making billiard balls of it. In addition, it is being used for cane and umbrella handles, checkers and dominoes, door knobs, buttons, clock cases, and the like, in imitation of the costly marbles.

A number of other projected uses for the new product are given at length, but those we have named will suffice to give an idea of its probable utility. From the very imperfect account given of its composition, we should incline to the opinion that "bonsilate" promises to be a very cheap substitute for the materials above named, but we doubt if it will be found adapted for as great a diversity of uses as celluloid.

PROGRESS IN UTILIZATION OF SOLAR HEAT.—Since May last year, M. Mouchot has been carrying on experiments near Algiers with his solar receivers. The smaller mirrors (0.80 m. diameter) have been used successfully for various operations in glass, not requiring more than 400° to 500°. Among these are the fusion and calcination of alum, preparation of benzoic acid, purification of linseed oil, concentration of sirups, sublimation of sulphur, distillation of sulphuric acid, and carbonization of wood in closed vessels. The large solar receiver (with mirror of 3.80 m.) has been improved by addition of a sufficient vapor chamber and of an interior arrangement which keeps the liquid to be vaporized constantly in contact with the whole surface of heating. This apparatus on November 18th, last year, raised 35 liters of cold water to the boiling point in 80 minutes, and an hour and a half later showed a pressure of eight atmospheres. On December 24th M. Mouchot with it distilled directly 25 litres of wine in 80 minutes, producing four litres of brandy. Steam distillation was also successfully done, but perhaps the most interesting results are those relating to mechanical utilization of solar heat. Since March the receiver has been working a horizontal engine (without expansion or condensation) at the rate of 120 revolutions a minute, under a constant pressure of 3.5 atmospheres. The disposable work has been utilized in driving a pump which yields six litres a minute at 3.50 m. or 1200 litres an hour at 1 m., and in throwing a water jet 12 m. This result, which M. Mouchot says could be easily improved, is obtained in a constant manner from 8 a. m. to 4 p. m., neither strong winds nor passing clouds sensibly affecting it.

REGNIER'S BATTERY.—A very promising new voltaic battery has been devised by M. Emil Regnier, the young Parisian electrician who invented the incandescent electric lamp known by his name. It may be generally described as a Daniell cell in which the sulphate of zinc solution is replaced by a solution of caustic potash. In detail, it consists of a zinc plate immersed in a solution of the alkali, and a copper plate immersed in a solution of the copper salt; the two solutions being separated by a porous partition of parchment paper made up in the form of a square bag. The electromotive force on charging this cell is 1.47 volts,

falling to 1.35 volts after it has been on "short circuit" for a considerable time. The internal resistance is 0.075 ohms. for a cell 5 in. high, and 12 cubic inches in capacity. According to tests made by M. Regnier the power of the battery for performing work, either by producing heat, mechanical power, or electrolysis, is twice greater than that of the ordinary Bunsen cell of physical laboratories. Moreover, the battery emits no volatile products, and its waste liquor may be regenerated by electrolysis into the original materials.

THE SAINT GOTHARD TUNNEL.—An unforeseen and very serious difficulty in the successful completion of the St. Gothard Tunnel recently declared itself. This was the sinking of the work over a length of about 100 yards, and to such an extent that it defied every effort on the part of the engineers to repair the repeated settlement of the roof. The formation at this unfortunate section consists of strata of gypsum and calcareous and aluminous schists, which absorb moisture very freely, and swell and disintegrate. So great was the trouble with this length that the almost desperate remedy of diverting the course of the tunnel so as to avoid it was seriously contemplated, and may even yet be necessary, although a method is now being adopted which promises extremely well. The dangerous portion is being enlarged and lined with granite walls, arching and invert, of great thickness. This lining, however, is not continuous, but built in independent lengths of about 12 ft. each, so that the settlement which ensues may affect only a short distance of the work. In commencing this labor the engineers first built the two end sections so as to obtain a sound abutment against the secure part of the lining, and from them lengths were advanced on each side towards the center. The thickness of the masonry at the center of the arch is 4 ft. 8 in., at the springing 8 ft. 3 in., and that of the invert is about 2 ft; only two more sections remain to be finished, five on the north and five on the south side having been completed. A Geneva correspondent writes:—"The engineers of the St. Gothard Tunnel seem to be in a fair way to overcome the difficulty arising from the falling in of the roof in the part known as the "windy stretch." This stretch, which is 200 meters long, and situated almost directly under the plain of Andermatt, passes through strata composed alternately of gypsum and aluminous and calcareous schists, which absorb moisture like a sponge, and swell on exposure to the atmosphere. It has given the contractors immense trouble, and has fallen in so often that it was seriously proposed a short time ago to allow it to collapse, and make a bend, so as to avoid the "windy stretch" altogether. The expedient now adopted, which has so far been successful, is the rebuilding of the supporting masonry in rings of solid granite. The rings are each four metres long, so that in the event of any one of them giving way the others will not thereby be affected. The building is constructed slowly and with the utmost care; no imperfect stones are allowed to be used; the masonry is perfect, and the walls of extraordinary thickness—in the parts most exposed to pressure not less than ten feet. At the beginning of June only 34 metres of the "windy stretch" required to be revaulted. The stories that have lately been going the round of the European Press touching the condition of the great tunnel, and the improbability of its being opened for traffic during the present year, would therefore appear to have little if any foundation in fact."

PRESERVING WOOD.—To a German technical journal, Privy Councilor Funk has contributed a valuable paper on the result of some experiments in preserving sleepers on the German and Austrian railways. The methods employed for impregnating the sleepers are well known, and the substances used were chloride of zinc, sulphate of copper, corrosive sublimate, and creosote. The latter is commonly used in this country, and from the manner of carrying out the process it becomes rather expensive. Herr Funk gives a table of the cost for oak, beech, and fir sleepers, from which it appears that the chloride of zinc is cheaper than the other preservatives, but costs more for beech than for either fir or oak. As compared with creosote, the only thing that gives an equal degree of durability, chloride of zinc, is about one-third the price, and the effect of impregnation is to bring fir sleepers into practical equality with the more costly woods. The life of sleepers, both impregnated and unimpregnated, depends largely upon the nature of the timber, and the manner in which the timber is treated before being made into sleepers, and the nature of the ballast in which the sleepers are laid; but by dealing with large numbers of sleepers employed under different conditions a fair idea can be obtained of the value of preservative processes. According to Herr Funk the average life of unimpregnated sleepers on German and Austrian railways up to the present time has been as follows: oak, 13.6; fir, 7.2; pine, 5.1; beech, 3.0 years.

On the same lines the average lives of sleepers properly treated and impregnated with chloride of zinc or creosote under heavy pressure have been: oak, 19.5; fir 14 to 16; pine, 8 to 10, beech, 15 to 18 years.

The prolongation of the life of the beech sleepers by impregnation is remarkable. Herr Funk adds that the average life of 831,341 pine sleepers impregnated on various systems, and used on thirteen German railways, was fourteen years.

Timber felled in winter is found to make more durable sleepers than that felled in summer, but what difference there is, is less marked in the impregnated sleepers than in those made of unprepared wood.